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REPORT

Note: This is a reference cited in *AP 42, Compilation of Air Pollutant Emission Factors, Volume I Stationary Point and Area Sources.* AP42 is located on the EPA web site at www.epa.gov/ttn/chief/ap42/

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PACIFIC ENVIRONMENTAL SERVICES, INC.

Revision of Tank Truck Loading Hydrocarbon Emission Factors

AP-42 Section 4.4: Transportation and Marketing of Petroleum Liquids

by

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1.0 INTRODUCTION

1.1 SUMMARY

An effort has been undertaken to revise the gasoline loading emission factors for the Transportation and Marketing of Petroleum Liquids, Section 4.4 in the Compilation of Air Pollutant Emission Factors, AP-42, Supplement No. 9. The tank car/truck emission factors presented in Table 4.4-3 of AP-42 were re-evaluated in terms of extensive field data collected by the U.S. Environmental Protection Agency (EPA) in conjunction with recent new source performance standard (NSPS) development.

Generally, existing factors for submerged loading of gasoline were corroborated by this new information. The small differences between the test data and existing factors are not considered significant enough to warrant any revision of the applicable emission factors. An important reason for this conclusion is that considerable variation exists among test runs on the same type of loading. The extent of this variation overshadows the differences between existing factors and averages calculated from the new data. Another reason is that the factors in Table 4.4-3 of AP-42 are considered to be estimates (with a probable error of ±30 percent),[1] and the new data fall well within this degree of variation.

Only very minimal data were collected for losses during splash loadings, so no conclusions could be drawn concerning these factors.

Several changes to Section 4.4 of AP-42 have been made as a result of background information developed for the NSPS for bulk gasoline terminals.[2] These changes improve clarity and introduce consistent metric units for the emission factors. For example, the metric units for emission factors have been changed from kg/10^3 liters to mg/liter. The new unit of emission measurement matches the unit developed under the NSPS, and is 1,000 times smaller than the unit previously used in AP-42 (i.e., 1 kg/10^3 liter = 1,000 mg/liter).

1.2 BASIS FOR REVISION EFFORT

The development of standards for bulk gasoline terminals actually began when a series of EPA-sponsored emission tests was initiated in 1973. These efforts were directed toward the eventual regulation of volatile organic compound (VOC) emissions from tank truck loading at terminals. A control techniques guideline (CTG) for VOC control at terminals was published in October 1977.[3] NSPS development for the bulk terminal source category was started in November 1978, with proposal of standards appearing in the Federal Register on December 17, 1980.[4]

All of the bulk terminal emission tests were performed at controlled terminals; i.e., terminals with vapor collection and processing systems. A total of 22 tests (generally 3 days each) was performed at 21 different bulk terminals. Of these 22 tests, 15 provided data which could be used as support information in this analysis. A total of 364 test runs (tank truck loadings) were examined. The loading emissions

from tank trucks were calculated from measurements of total hydrocarbon concentration and gas flow at the inlet to the vapor processor. Section 4 contains further information on the testing.

1.3 BACKGROUND OF EXISTING EMISSION FACTORS

The current loading emission factors in Table 4.4-3 of AP-42 are calculated (within ±30 percent) using the following expression:

$$L_L = 12.46 \frac{SPM}{T}, \tag{1}$$

where: L_L = Loading loss, lb/10^3 gal of liquid loaded.
P = True vapor pressure of liquid loaded, psia.
M = Molecular weight of vapors, lb/lb-mole.
T = Bulk temperature of liquid loaded, °R.
S = A saturation factor.

This expression is theoretically derived starting with the ideal gas equation,

$$PV = nRT = \frac{W}{M} RT, \tag{2}$$

where: n = number of moles of vapor.
R = gas constant = $10.73 \frac{lb}{in^2} \frac{ft^3}{(lb\text{-}mole)(°R)}$.
V = vapor volume, ft^3.
W = vapor weight, lb.

The symbols P, T, and M have the same meanings defined for equation (1).

The loading loss is considered to be:

$$L_L(lb/ft^3) = \frac{W}{V}. \tag{3}$$

Combining with equation (2),

$$L_L(lb/ft^3) = \frac{PM}{RT}. \tag{4}$$

Substituting the value for R, converting ft^3 to gal, and inserting the saturation factor,

$$L_L = \frac{1}{10.73} \frac{SPM}{T} \frac{ft^3}{7.481\ gal}$$

$$= 0.01246 \frac{SPM}{T} (lb/gal)$$

or,

$$L_L = 12.46 \frac{SPM}{T} (lb/10^3\ gal),$$

which is equation (1).

The saturation factor S is inserted in the loading loss expression to represent the expelled vapor's fractional approach to saturation, and this factor alone accounts for the variations in the emission rates under various types of loading. The saturation factor can be estimated as:

$$S = 0.803 \frac{dT}{PM} (L), \tag{5}$$

where: d = product density at temperature T, lb/gal.
L = evaporation loss during loading, percent.

This expression is merely a rearrangement of equation (1):

$$S = \frac{1}{12.46} \frac{L_L T}{PM}$$

$$= 0.803 \frac{L_L T}{PM} \tag{6}$$

Combining with equation (3), the product density term is inserted as follows,

$$S = 0.803 \frac{dT}{PM} (L),$$

to produce equation (5). The units of L_L ($lb/10^3$ gal) have been assumed by the density parameter d and the now-dimensionless loading loss parameter L.

Values of L were determined experimentally in several field tests under various conditions and reported by the American Petroleum Institute (API).[1] In 44 submerged loading tests (35 gasoline, 9 crude oil) and 56 splash loading tests (38 gasoline, 18 crude oil), losses were measured as a weight percentage of the loaded product. The resulting values of S in Table 4.4-1 of AP-42 represent averages from these tests.

The test data presented in this document represent a considerable body of new information which can be compared with the existing AP-42 emission factors. However, two very different approaches to emission factor calculation are involved, and caution should be exercised in comparing results in the two cases. Section 3.3 discusses this subject further.

2.0 THE BULK GASOLINE TERMINAL INDUSTRY

2.1 INTRODUCTION

A bulk gasoline terminal is typically any petroleum marketing facility which receives gasoline from refineries by pipeline, ship, or barge; stores it in large above-ground tanks; and dispenses it into tank trucks for delivery to customers. Only facilities with an average gasoline throughput greater than 76,700 liters (20,000 gallons) per day are considered bulk terminals, in order to distinguish them from the smaller distribution facilities known as bulk plants. Only a small number (less than 2 percent) of bulk terminals dispense gasoline into tank rail cars. Gasoline is delivered from bulk terminals to bulk plants, or directly to retail accounts. Terminals handle several petroleum products in addition to gasoline, including diesel fuel and heating oil.

There are presently an estimated 1,511 bulk terminals storing gasoline in the U.S. About half of these terminals receive products from refineries by pipeline, and half receive products by ship or barge delivery. Gasoline is defined as a petroleum distillate or petroleum distillate/alcohol blend having a Reid Vapor Pressure (RVP) of 27.6 kPa (4 psi) or greater that is used as fuel for internal combustion engines.

Bulk gasoline terminals serve as redistribution points for the gasoline produced at refineries. As such, they do not perform any processing operations on the gasoline, although sometimes additives are mixed with gasoline at terminals. All movement of gasoline at a bulk terminal involves only loading, unloading, and transfer. Gasoline stored in tanks is pumped through metered loading areas, called loading racks, and into delivery tank trucks, which service various wholesale and retail accounts in the marketing network.

2.2 GASOLINE LOADING METHODS

Loading racks contain the equipment necessary to fill delivery tank trucks with liquid product. A typical loading rack includes fuel loading arms, pumps, meters, shutoff valves, relief valves, check valves, electrical grounding, and lighting. Terminals generally utilize two to four rack positions for gasoline, each having from one to four loading arms. Loading may be performed using either top splash, top submerged, or bottom loading methods.

2.2.1 Top Loading

Top loading is divided into top splash loading, with or without vapor collection, top submerged, and top-tight submerged loading. Top loading involves loading of products into a tank compartment via the hatchway which is located on top of the tank. Gasoline is loaded directly into the compartment through a top loading fill pipe (splash fill). Attachment of a fixed or extensible downspout to the fill pipe provides a means of introducing the product near the bottom of the tank (submerged fill). Top splash loading creates more turbulence than submerged loading and can create a vapor mist in the air space above the incoming product.

Top loading can also be designed for vapor collection. A top loading vapor head, compatible with the tank hatch opening, creates a vapor-tight seal between the loading head and the hatch to minimize vapor leakage during transfer of product. An annular space in the vapor head routes vapors into the vapor collection system.

In a top-tight submerged fill installation, the loading of product is performed through a vapor-tight loading adapter permanently mounted on top of each compartment and attached to a fixed submerged fill pipe. For vapor collection, the vapor spaces of each compartment are routed to the overturn rail or to a vapor return line. Vapors from all compartments are manifolded together into one vapor line. One advantage of this permanently affixed top-tight submerged fill system is that the hatch/dome covers remain closed at all times except for cleanup and repair. This minimizes wear on the hatch and vapor containment equipment. The top-tight and vapor head systems allow the collection of vapors expelled from the tank during product loading.

The top-tight loading system is not in widespread use at terminals. Simplified loading combined with vapor collection is generally accomplished using bottom loading.

2.2.2 Bottom Loading

Bottom loading refers to the loading of products into the cargo tank through loading adapters located at the bottom of the tank. Submerged loading occurs using this method, and turbulence is again held to a minimum. Some of the advantages cited for bottom loading include: (1) improved safety, (2) faster loading, and (3) reduced labor costs. Safety is improved since the operator does not have to climb on top of the truck. This is especially advantageous

during wet or icy conditions when the top of the truck may be slippery. Loading can be accomplished in a shorter time because all the equipment is at ground level where it can be easily handled by the operator. Faster loadings reduce labor costs because more loadings can be done per labor-hour.

Loading gasoline into a tank truck through bottom connectors is a simple operation. Dry-break couplers are used to attach loading arms to trucks so that liquid loss can be minimized during connecting and disconnecting. For vapor collection, a flexible hose or swing-type arm is usually connected during loading to a vapor collection line on the truck. This line routes gasoline vapors to a vapor collection and processing system.

2.3 FACTORS AFFECTING EMISSIONS

Without emission controls on the loading operation, the quantities of VOC emitted depend on such factors as the loading method used and the concentration of vapors in the tank truck at the start of loading.

A survey[5] covering approximately 1,900 tank vehicles, or about 2 percent of the gasoline tank truck population, indicated that 22.8 percent of tank trucks have only top loading, while the remaining 77.2 percent can be either top or bottom loaded. The trend is toward more trucks using bottom loading, due to State vapor recovery regulations and the advantages cited earlier.

The emissions from loading trucks in "balance service" are affected by the concentration of vapors in the tank air space during loading. "Balance service" refers to a system in which tank trucks exchange their liquid gasoline for the vapors displaced during unloading into gasoline storage tanks at the service station or bulk plant. The

amount of vapors exchanged depends on the vapor tightness of the tank truck. If leaks exist, air can enter the truck compartment during unloading, and the amount of vapors transferred, and hence the concentration in the compartment, is less than it would be in a vapor-tight system. VOC vapor levels may approach saturation in a tank truck servicing delivery points where a vapor balance system is utilized. The requirement for vapor balancing of tank trucks is expected to be put into effect in areas where bulk terminals are regulated under State Implementation Plans (SIP's). The term "normal service" is used to describe the situation in which vapor balancing is not used, and ambient air is allowed to enter the tank compartment during unloading.

Bulk gasoline terminals may handle liquid petroleum products other than gasoline. VOC emissions from products such as fuel oil, diesel, and jet fuel can be considered negligible when compared to gasoline, because of the much lower vapor pressures of these products. At many terminals, "switch loading" of delivery tank trucks is practiced. Switch loading involves the transport, in a single tank compartment on successive deliveries, of other products in addition to gasoline. Gasoline vapors can be displaced either by incoming gasoline or by any other liquid product when vapors from a previous load of gasoline are left in the delivery tank. Therefore, for the purpose of this study, it was important that the emission test reports designate the previous load of each tank truck being tested. As an example, fuel oil loaded into a tank compartment which had carried gasoline on the previous load would displace gasoline vapors, producing VOC emissions. Thus, VOC emissions can occur at gasoline loading racks, and also at product loading racks which switch load into tank trucks that transport gasoline.

Although several combinations of products loaded and type of service occurred in the EPA tests, only test runs in which gasoline was loaded and in which gasoline was the previous load were utilized as support information.

Since there are no other processes (such as combustion or chemical processes) associated with the loading of gasoline into tank trucks at bulk terminals, the only emissions from the operation are hydrocarbon compounds consisting of the gasoline vapors displaced from tank trucks during loading. These compounds consist primarily of C_4 and C_5 paraffins and olefins, which are photochemically reactive (precursors to ozone), as well as smaller amounts of lighter hydrocarbons, such as methane (C_1) and ethane (C_2). EPA has exempted from regulation methane and ethane because of their negligible photochemical reactivity.[6] Therefore, the regulated pollutant, volatile organic compounds (VOC), consists of all of the component compounds in the gasoline vapors except methane and ethane.

The EPA emission tests measured total hydrocarbons (as propane or butane), and measurements were not taken in most tests to allow the results to be converted to VOC (by subtracting out methane and ethane). Measurements in some tests[7,8] indicate that the weight percent of methane and ethane in gasoline vapors is very small, probably on the order of 0.5 percent and less for methane, and 0.2 percent and less for ethane. For this reason, the emission factor estimates derived from total hydrocarbon measurements are presumed to be essentially identical to the VOC emission factors, and the test data are used

directly to represent VOC emissions. The designation "VOC" is used throughout the balance of this document to reflect the data collected in the EPA testing which supported the NSPS development.

3.0 DETERMINATION OF REPRESENTATIVE EMISSION FACTORS

3.1 EMISSION DATA AND CALCULATION METHODS

3.1.1 Available Emission Data

The objective of this report is to provide a record of the effort to revise the AP-42 VOC emission factor values for loading operations at bulk gasoline marketing terminals. Section 4 contains summaries of the emission tests used in this effort. It is from the data obtained from these emission tests that representative emission factor values were developed. These tests were measurements of actual tank truck loadings carried out at several commercial bulk terminals during normal business operations, and were the only available tests during which emissions were measured on a single tank truck basis, rather than over some longer time period.

Tables 3-1 and 3-2 present the support data for the two emission source categories for which substantial data were available: Submerged Loading--Balance Service, and Submerged Loading--Normal Service. Notes and definitions of terms used in these tables are contained on page 3-20. Emission factors currently in use for these emission source categories are contained in Table 4.4-3, Section 4.4 of AP-42. The two splash loading categories in Table 4.4-3 were not re-evaluated because data were not adequate to warrant a revision of the current emission factors for these categories. It was found that Test No. 13 did not corroborate

Table 3-1. TEST DATA FOR SUBMERGED LOADING--BALANCE SERVICE

Test Number	Test Date	Run Number	$(V/L)_r$	$(V/L)_p$	F factor	$(M/L)_r$ (lb/10³ gal)	$(M/L)_p$ (lb/10³ gal)	C_r
1	5/25/77	1	0.691	1.0[1]	1.45	5.47	7.91	
		2	0.726	1.0	1.38	6.35	8.75	
		3	0.744	1.0	1.34	5.42	7.30	
		4	0.605	1.0	1.65	4.01	6.64	
		5	0.824	1.0	1.21	5.23	6.35	
		6	0.937	1.0	1.07	8.71	9.31	
		7	0.058	1.0	17.25	0.38	6.46	
		8	0.653	1.0	1.53	5.97	9.15	
		9	0.887	1.0	1.13	7.85	8.84	
		10	0.859	1.0	1.16	7.65	8.91	
		11	0.955	1.0	1.05	9.90	10.36	
	5/26/77	1	0.670	1.0[1]	1.49	6.77	10.10	
		2	0.968	1.0	1.03	10.10	10.43	5.09[5]
		3	0.852	1.0	1.17	7.96	9.35	
		4	0.412	1.0	2.43	4.23	10.27	
		6	0.853	1.0	1.17	7.56	8.86	
		7	0.329	1.0	3.04	3.48	10.58	
		8	0.891	1.0	1.12	6.24	7.01	4.27
		9	0.830	1.0	1.21	7.25	8.73	1.82
	5/27/77	1	0.497	1.0[1]	2.01	3.51	7.06	
		2	0.856	1.0	1.17	6.79	7.94	3.58
		3	0.120	1.0	8.33	0.95	7.89	
		4	0.746	1.0	1.34	3.00	4.01	
		5	1.006	1.0	0.99	7.17	7.12	
		6	0.864	1.0	1.16	8.42	9.74	
		7	0.592	1.0	1.69	4.12	6.97	
		9	0.937	1.0	1.07	7.01	7.47	4.63
		10	0.725	1.0	1.38	5.49	7.56	
		11	0.627	1.0	1.60	6.35	10.12	
		12	0.985	1.0	1.02	8.66	8.80	
		13	0.759	1.0	1.32	6.66	8.77	

Table 3-1. TEST DATA FOR SUBMERGED LOADING--BALANCE SERVICE
(Continued)

Test Number	Test Date	Run Number	$(V/L)_r$	$(V/L)_p$	F factor	$(M/L)_r$ (lb/10³ gal)	$(M/L)_p$ (lb/10³ gal)	C_r
2	2/28/78	2	0.699	1.0[2]	1.43	2.07	2.96	23.3[6]
	3/2/78	6	0.770	1.0[2]	1.30	2.93	3.81	17.8
	3/3/78	1	0.484	1.0[2]	2.07	1.46	3.01	13.6
3	10/24/78	1	1.051	1.07	1.02	4.62	4.72	20.4[6]
		2	0.965	1.07	1.11	5.77	6.39	27.7
		3[3]	1.159	1.07	0.92	7.56	6.99	30.2
		4[3]	1.062	1.07	1.01	6.73	6.77	28.7
		5	1.047	1.07	1.02	5.40	5.51	24.2
		6	1.055	1.07	1.01	6.15	6.24	27.7
		7	1.010	1.07	1.06	6.90	7.32	31.0
		8[3]	0.965	1.07	1.11	6.86	7.72	34.3
		9[3]	1.047	1.07	1.02	7.45	7.61	34.1
		10	1.077	1.07	0.99	7.07	7.03	31.9
		11	1.055	1.07	1.02	6.08	6.17	28.2
		12[3]	0.981	1.07	1.09	7.18	7.83	35.7
		13[3]	1.179	1.07	0.91	7.81	7.10	32.1
		14[3]	1.017	1.07	1.05	7.39	7.78	35.7
	10/25/78	15	1.062	1.07	1.01	6.75	6.79	29.5
		16[3]	1.100	1.07	0.97	6.55	6.37	27.6
		17[3]	1.002	1.07	1.07	5.35	5.71	25.6
		18	1.077	1.07	0.99	2.91	2.89	24.6
		19	1.107	1.07	0.97	6.19	6.00	26.5
		10	1.054	1.07	1.02	6.61	6.72	30.0
		21[3]	1.085	1.07	0.98	7.68	7.58	34.2
		22	0.987	1.07	1.08	7.10	7.69	34.9
		23	0.987	1.07	1.08	5.40	5.86	26.8
		24	1.115	1.07	0.96	5.39	5.18	23.7
		25	1.047	1.07	1.02	8.66	8.84	40.7
		26	1.040	1.07	1.03	8.31	8.55	38.9

Table 3-1. TEST DATA FOR SUBMERGED LOADING--BALANCE SERVICE
(Continued)

Test Number	Test Date	Run Number	$(V/L)_r$	$(V/L)_p$	F factor	$(M/L)_r$ (lb/10³ gal)	$(M/L)_p$ (lb/10³ gal)	C_r
	10/26/78	27	1.06	0.957	0.90	7.52	6.79	33.8
		28	0.95	0.957	1.01	8.49	8.55	33.8
		29	1.01	0.957	0.95	8.31	7.87	39.3
		30	1.08	0.957	0.89	7.65	6.79	33.8
		31	1.04	0.957	0.92	7.30	6.72	34.3
		32	1.01	0.957	0.95	7.23	6.86	34.3
		34	1.00	0.957	0.96	6.97	6.68	33.5
		35[3]	0.97	0.957	0.99	7.54	7.43	38.0
		36	1.10	0.957	0.87	7.58	6.59	33.3
		37	1.08	0.957	0.87	6.97	6.06	31.1
		39[3]	0.98	0.957	0.98	7.65	7.50	37.5
		40	1.08	0.957	0.89	4.72	4.20	21.1
5	1/25/78	2	0.839	1.0[2]	1.19	5.67	6.74	31.7[6]
		8	0.655	1.0	1.53	5.12	7.83	37.1
		9	0.839	1.0	1.19	5.95	7.08	33.5
		10	0.774	1.0	1.29	5.69	7.34	33.5
		11	0.864	1.0	1.16	5.91	6.85	32.3
	1/26/78	3	0.754	1.0[2]	1.33	5.00	6.66	32.2
		7	0.650	1.0	1.54	4.12	6.35	30.8
		9	0.870	1.0	1.15	5.67	6.52	30.8
	1/27/78	2	0.756	1.0[2]	1.32	4.28	5.65	26.3
		3	0.837	1.0	1.19	4.59	5.46	25.7
		5	0.826	1.0	1.21	2.38	2.88	13.5
		7	0.904	1.0	1.11	5.45	6.04	28.1
	1/30/78	1	0.956	1.0[2]	1.05	4.54	4.77	21.6
		3	0.983	1.0	1.02	3.84	3.91	18.0
		5	0.465	1.0	2.15	1.98	4.27	19.8
		6	0.967	1.0	1.03	5.00	5.16	24.0
		8	0.594	1.0	1.68	3.29	5.52	25.7

Table 3-1. TEST DATA FOR SUBMERGED LOADING--BALANCE SERVICE (Continued)

Test Number	Test Date	Run Number	$(V/L)_r$	$(V/L)_p$	F factor	$(M/L)_r$ (lb/10³ gal)	$(M/L)_p$ (lb/10³ gal)	C_r
6	1/10/78	1	0.800	1.0[1]	1.25	3.79	4.74	27.9[7]
		2	0.933	1.0	1.07	5.69	6.09	35.9
		3	0.910	1.0	1.10	6.26	6.89	40.5
		4	0.904	1.0	1.11	4.74	5.26	31.1
		5	0.899	1.0	1.11	4.63	5.14	30.4
	1/11/78	7	0.839	0.963	1.15	3.64	4.18	25.6
		8	0.821	0.963	1.17	1.06	1.24	7.5
		9	0.880	0.963	1.09	2.89	3.15	19.4
		10	0.940	0.963	1.02	4.08	4.16	25.9
		11	0.565	0.963	1.70	2.05	3.49	21.5
		12	0.430	0.963	2.24	1.74	3.90	14.1
		13[3]	0.963	0.963	1.00	0.31	0.31	1.9
		14	0.666	0.963	1.45	3.35	4.86	30.1
		15	0.917	0.963	1.05	3.02	3.17	19.9
		16	0.848	0.963	1.14	1.04	1.18	7.3
		17	0.691	0.963	1.40	3.97	5.56	34.6
		19	1.010	0.963	0.95	3.62	3.44	21.4
		20	1.010	0.963	0.95	5.18	4.92	30.8
		21	0.732	0.963	1.32	2.56	3.38	20.5
	1/12/78	22	0.495	1.0[1]	2.02	1.65	3.34	19.4
		23	0.844	1.0	1.19	2.36	2.81	16.4
		24	0.836	1.0	1.20	0.73	0.87	5.2
		25	0.683	1.0	1.47	4.47	6.58	38.7
		26	0.811	1.0	1.23	2.78	3.42	20.2
		27	0.796	1.0	1.26	3.97	5.00	29.7
		28	1.030	1.0	0.97	6.66	6.45	38.9
		29	0.822	1.0	1.22	3.84	4.68	27.7
		30	0.929	1.0	1.08	6.61	7.14	43.0
		31	0.730	1.0	1.37	5.80	7.94	48.1

Table 3-1. TEST DATA FOR SUBMERGED LOADING--BALANCE SERVICE
(Continued)

Test Number	Test Date	Run Number	$(V/L)_r$	$(V/L)_p$	F factor	$(M/L)_r$ (lb/10³ gal)	$(M/L)_p$ (lb/10³ gal)	C_r
7	2/23/78	5-2	0.805	1.0[2]	1.24	2.14	2.65	11.8[6]
		5-3	0.899	1.0	1.11	3.66	4.06	18.4
		5-4	0.625	1.0	1.60	2.73	4.37	19.7
		5-6	1.04	1.0	0.96	2.38	2.29	10.5
		6-1	1.08	1.0	0.93	1.74	1.62	7.2
		6-3	0.467	1.0	2.14	0.79	1.70	7.9
		6-5	0.522	1.0	1.82	1.94	3.53	17.1
		6-6	0.491	1.0	2.04	1.48	3.01	13.8
		6-7	0.863	1.0	1.16	4.43	5.14	23.7
		6-8	0.874	1.0	1.15	2.84	3.27	15.1
		6-9	0.871	1.0	1.15	4.94	5.68	26.3
	2/24/78	5-2	0.983	1.0[2]	1.02	5.86	5.98	27.3
		5-3	0.871	1.0	1.15	5.16	5.93	27.3
		5-4	0.885	1.0	1.13	4.76	5.38	24.7
		5-6	0.976	1.0	1.03	4.81	4.95	22.7
		5-7	0.784	1.0	1.28	3.64	4.66	21.3
		5-8	0.864	1.0	1.16	4.23	4.91	22.6
		5-11	0.612	1.0	1.63	2.60	4.24	19.9
		5-12	0.769	1.0	1.30	4.45	5.79	26.8
		6-1	0.624	1.0	1.60	3.81	6.10	27.9
		6-2	0.848	1.0	1.18	3.51	4.14	18.9
		6-3	0.982	1.0	1.02	4.92	5.02	22.8
		6-5	0.775	1.0	1.29	4.81	6.20	28.7
		6-9	0.908	1.0	1.10	3.64	4.00	18.7
		6-10	0.658	1.0	1.52	3.22	4.89	22.6
		6-11	0.693	1.0	1.44	3.59	5.18	24.0
	2/27/78	5-2	0.812	1.0[2]	1.23	4.32	5.32	24.0
		5-3	0.594	1.0	1.68	3.33	5.59	25.3
		5-4	0.677	1.0	1.48	3.97	5.87	26.6
		5-5	0.635	1.0	1.57	2.98	4.67	21.4
		5-6	0.786	1.0	1.27	3.75	4.76	22.1

Table 3-1. TEST DATA FOR SUBMERGED LOADING--BALANCE SERVICE
(Continued)

Test Number	Test Date	Run Number	$(V/L)_r$	$(V/L)_p$	F factor	$(M/L)_r$ (lb/10³ gal)	$(M/L)_p$ (lb/10³ gal)	C_r
7	2/27/78	6-1	0.828	1.0	1.21	1.90	2.29	10.4
		6-2	0.658	1.0	1.52	3.73	5.66	25.6
		6-3	0.871	1.0	1.15	5.51	6.34	28.6
		6-4	0.862	1.0	1.16	3.95	4.58	20.8
		6-5	0.819	1.0	1.22	5.38	6.56	29.9
		6-8	0.873	1.0	1.15	5.20	5.98	27.3
9	9/20/76	11A	0.870	1.05	1.21	5.62	6.80	51.2[7]
		6B	0.281	1.05	3.74	1.08	4.03	
	9/21/76	4A[3]	0.703	1.0[1]	1.42	3.95	5.60	37.4
	9/22/76	8A[3]	0.944	0.843	0.89	4.06	3.61	32.9
		6B[3]	0.837	0.843	1.01	5.47	5.52	51.8
10	11/10/76	2	0.730	1.04	1.43	2.42	3.44	20.7[7]
		13[3]	1.080	1.04	0.96	4.06	3.92	23.7
		7[3]	0.973	1.03	1.06	5.41	5.73	33.7
		12[3]	0.990	1.03	1.04	5.58	5.80	34.3
12	9/26/78	3[3]	0.741	0.915	1.23	4.74	5.83	30.2[6]
		4	0.819	0.915	1.12	6.26	7.01	35.8
		8[3]	0.945	0.915	0.97	5.14	4.97	25.8
		11	1.04	0.915	0.88	7.21	6.34	33.2
		14	0.763	0.915	1.20	5.45	6.53	34.1
		17[3]	0.923	0.915	0.99	7.72	7.64	39.9
		18	0.792	0.915	1.16	6.61	7.67	41.0
		22	0.967	0.915	0.95	8.33	7.92	42.9
	9/27/78	2	0.928	0.953	1.03	7.23	7.45	36.5
		3	0.920	0.953	1.04	6.70	6.97	34.5
		4	0.929	0.953	1.03	4.76	4.91	24.2
		5	1.00	0.953	0.95	7.76	7.40	36.6
		11	2.00	0.953	0.48	14.31	6.87	34.5
		12	1.14	0.953	0.84	8.86	7.44	38.0
		14	0.953	0.953	1.00	2.25	2.25	36.6

Table 3-1. TEST DATA FOR SUBMERGED LOADING--BALANCE SERVICE
(Continued)

Test Number	Test Date	Run Number	$(V/L)_r$	$(V/L)_p$	F factor	$(M/L)_r$ (lb/10³ gal)	$(M/L)_p$ (lb/10³ gal)	C_r
12	9/27/78	16[3]	0.896	0.953	1.06	5.00	5.31	27.0
		20	0.932	0.953	1.02	10.10	10.30	52.3
		22	0.944	0.953	1.01	7.47	7.55	39.2
		23	0.829	0.953	1.15	7.12	8.19	41.4
	9/28/78	1	0.915	1.06	1.16	7.74	8.98	42.0
		4B[3]	0.889	1.06	1.19	6.99	8.32	39.0
		5	1.10	1.06	0.96	6.26	6.01	28.2
16	2/20/78	2	0.793	1.0[2]	1.26	4.65	5.86	27.4[6]
		3	0.705	1.0	1.42	4.03	5.73	28.0
		4	0.705	1.0	1.42	4.03	5.73	25.5
		8	0.684	1.0	1.46	4.01	5.86	27.4
		10	0.725	1.0	1.38	2.38	3.29	15.5
		12	0.569	1.0	1.76	3.51	6.17	28.9
		13	0.656	1.0	1.52	3.66	5.56	26.8
	2/21/78	1	0.681	1.0[2]	1.47	3.95	5.80	26.6
		3	0.647	1.0	1.55	3.46	5.36	24.7
		4	0.671	1.0	1.49	3.64	5.42	25.1
		5	0.720	1.0	1.39	3.90	5.42	25.4
		6	0.441	1.0	2.27	1.57	3.55	16.7
		7	0.630	1.0	1.59	3.22	5.12	23.7
		8	0.778	1.0	1.29	4.45	5.75	26.8
		9	0.663	1.0	1.51	3.79	5.73	26.8
		10	0.778	1.0	1.29	4.28	5.52	25.8
		11	0.553	1.0	1.81	1.48	2.67	12.5
		12	0.780	1.0	1.28	2.16	2.77	13.2
		13	0.707	1.0	1.41	1.97	2.80	13.2
		14	0.738	1.0	1.36	4.06	5.52	25.8
		15	0.495	1.0	2.02	2.62	5.30	24.7
		16	0.613	1.0	1.63	3.51	5.71	26.8
		17	0.644	1.0	1.51	3.75	5.66	26.1

Table 3-1. TEST DATA FOR SUBMERGED LOADING--BALANCE SERVICE
(Continued)

Test Number	Test Date	Run Number	$(V/L)_r$	$(V/L)_p$	F factor	$(M/L)_r$ (lb/10³ gal)	$(M/L)_p$ (lb/10³ gal)	C_r
16	2/21/78	18	0.728	1.0	1.37	4.28	5.86	27.1
		19	0.770	1.0	1.30	4.59	5.96	27.4
		20	0.835	1.0	1.20	4.92	5.90	27.4
17	5/2/78	1	0.934	1.0[2]	1.07	6.75	7.22	35.3[6]
	5/3/78	1	0.553	1.0[2]	1.81	2.69	4.87	23.5
		2	0.909	1.0	1.10	5.75	6.33	31.2
		5	0.857	1.0	1.17	6.46	7.56	38.3
	5/4/78	5	0.814	1.0[2]	1.23	4.43	5.45	26.9
		6	0.219	1.0	4.57	0.53	2.42	11.9
		8	0.613	1.0	1.63	4.39	7.15	34.9
18	8/2/78	18	1.02	0.936	0.92	8.36	7.69	39.9[6]
		23	0.438	0.936	2.14	2.69	5.76	30.4
	8/3/78	15	0.761	1.34	1.76	8.00	14.09	52.6
	8/4/78	13	0.941	1.11	1.18	7.41	8.74	39.0
		14	0.750	1.11	1.48	7.58	11.22	50.0
		15	1.04	1.11	1.07	10.16	10.88	48.5
		16	0.756	1.11	1.47	7.45	10.95	48.5
		21	1.53	1.11	0.73	15.76	11.43	51.2
19	9/21/78	1	0.828	1.05	1.27	7.87	9.99	46.5[6]
		3[3]	0.958	1.05	1.10	9.28	10.21	47.6
		7	0.896	1.05	1.17	11.44	13.39	61.9
		8[3]	0.605	1.05	1.74	21.16	36.82	35.5
		10	1.03	1.05	1.02	10.10	10.30	47.7
		11[3]	1.17	1.05	0.89	10.54	9.38	44.6
		13[3]	0.963	1.05	1.09	10.03	10.93	51.5
		15	1.01	1.05	1.04	10.21	10.62	50.5

Table 3-1. TEST DATA FOR SUBMERGED LOADING--BALANCE SERVICE (Continued)

Test Number	Test Date	Run Number	$(V/L)_r$	$(V/L)_p$	F factor	$(M/L)_r$ (lb/10³ gal)	$(M/L)_p$ (lb/10³ gal)	C_r
20	2/1/78	1	0.608	1.0[2]	1.65	2.93	4.84	22.0[6]
		3	0.804	1.0	1.24	4.39	5.44	25.0
		10	0.356	1.0	2.81	1.32	3.71	17.0
	2/2/78	1	0.744	1.0[2]	1.34	3.13	4.20	19.0
		6	0.709	1.0	1.41	2.95	4.17	19.0
		7	0.712	1.0	1.40	3.90	5.46	25.0
		8	0.751	1.0	1.33	3.13	4.16	19.0
		11	1.05	1.0	0.95	2.54	2.41	11.0
		13	0.974	1.0	1.03	4.03	4.16	19.0
		15	0.624	1.0	1.60	2.04	3.27	15.0
		16	0.694	1.0	1.44	3.86	5.56	25.8
		18	0.178	1.0	5.62	0.89	5.02	23.0
		19	0.593	1.0	1.69	2.49	4.21	19.0
		20	0.575	1.0	1.74	3.09	5.37	24.0
	3/6/78	5	0.648	1.0[2]	1.54	1.72	2.65	12.5
	3/7/78	1	0.866	1.0[2]	1.15	6.86	7.89	35.7
		2	0.811	1.0	1.23	6.33	7.78	35.7
		3	0.879	1.0	1.14	6.55	7.46	33.5
		4	0.872	1.0	1.15	4.23	4.87	22.5
		5	0.874	1.0	1.15	5.12	5.88	27.2
		6	0.439	1.0	2.27	2.69	6.11	28.6
		7	0.888	1.0	1.13	5.86	6.63	30.6
21	8/16/78	4	1.05	1.0[1]	0.95	12.19	11.58	58.2[6]
		5	0.907	1.0	1.10	9.85	10.84	52.5
		6	0.941	1.0	1.06	10.80	11.45	55.4
		7	0.917	1.0	1.09	9.72	10.60	52.6
	8/17/78	1	0.893	0.987	1.11	11.68	12.97	64.2
		2	0.990	0.987	0.99	10.80	10.69	52.5
		3	1.01	0.987	0.98	12.59	12.34	62.7
		4	0.836	0.987	1.18	8.36	9.86	48.4
		5	1.02	0.987	0.97	11.22	10.89	55.4
		6	0.489	0.987	2.02	6.88	13.89	68.1
		7	1.00	0.987	0.99	9.61	9.49	47.7

Table 3-1. TEST DATA FOR SUBMERGED LOADING--BALANCE SERVICE
(Continued)

Test Number	Test Date	Run Number	$(V/L)_r$	$(V/L)_p$	F factor	$(M/L)_r$ (lb/10³ gal)	$(M/L)_p$ (lb/10³ gal)	C_r
21	8/17/78	8[3]	0.902	0.987	1.09	11.55	12.59	61.8
		9[3]	0.969	0.987	1.02	10.58	10.79	53.3
		10	1.05	0.987	0.94	13.12	12.33	62.7
		11	0.968	0.987	1.02	11.33	11.56	56.0
	8/18/78	2	0.956	1.07	1.12	10.78	12.07	54.9
		6	0.934	1.07	1.15	6.92	7.96	35.6
		7[3]	0.065	1.07	16.46	0.25	4.15	19.2
		8[3]	1.07	1.07	1.00	12.26	12.26	57.4
		9[3]	1.06	1.07	1.01	11.12	11.31	51.8
		10	1.29	1.07	0.83	17.2	14.30	66.6
		11	1.16	1.07	0.92	15.32	14.10	66.6
		14	1.02	1.07	1.05	12.37	12.99	62.5
		15	1.17	1.07	0.92	10.54	9.70	44.0

Notes and definitions on page 3-20.

Table 3-2. TEST DATA FOR SUBMERGED LOADING--NORMAL SERVICE

Test Number	Test Date	Run Number	$(V/L)_r$	$(V/L)_p$	F factor	$(M/L)_r$ (lb/10³ gal)	$(M/L)_p$ (lb/10³ gal)	C_r
2	2/28/78	1	0.699	1.0[2]	1.43	2.07	2.96[4]	6.7[6]
	3/1/78	2	0.453	1.0[2]	2.21	1.35	2.97	13.6
		3	0.761	1.0	1.32	2.93	3.87	17.7
		5	0.731	1.0[2]	1.37	1.92	2.63	12.0
	3/2/78	1	0.414	1.0[2]	2.42	0.95	2.29	10.6
		2	0.739	1.0	1.35	0.77	1.04[4]	4.8
		3	0.756	1.0	1.32	0.75	0.99[4]	4.5
		4	0.971	1.0	1.03	1.30	1.34[4]	6.2
		7	0.915	1.0	1.09	2.16	2.36	11.0
		8	0.778	1.0	1.29	3.46	4.46[4]	20.6
		9	0.817	1.0	1.22	1.59	1.94[4]	8.9
		10	0.778	1.0[2]	1.29	2.29	2.96[4]	13.6
	3/3/78	3	0.379	1.0[2]	2.64	1.65	4.37	20.0
3	10/26/78	33	0.92	0.957	1.04	6.55	6.81	34.3[6]
		38	1.09	0.957	0.88	7.23	6.36	31.2
5	1/25/78	7	0.824	1.0[2]	1.21	4.56	5.52	26.3[6]
		12	0.932	1.0[2]	1.07	3.53	3.77[4]	18.0
	1/26/78	1	0.954	1.0[2]	1.05	2.16	2.27[4]	11.2
	1/27/78	1	0.956	1.0[2]	1.05	1.94	2.04	9.6
		4	0.953	1.0	1.05	1.90	1.99	9.3
		6	0.825	1.0	1.21	3.18	3.84	18.3
		8	0.647	1.0	1.55	2.67	4.14	19.2
		9	0.728	1.0[2]	1.37	2.38	3.26	15.0
	1/30/78	2	0.933	1.0[2]	1.07	2.82	3.02	13.8
		4	0.962	1.0	1.04	3.35	3.49	15.9

Table 3-2. TEST DATA FOR SUBMERGED LOADING--NORMAL SERVICE (Continued)

Test Number	Test Date	Run Number	$(V/L)_r$	$(V/L)_p$	F factor	$(M/L)_r$ (lb/10³ gal)	$(M/L)_p$ (lb/10³ gal)	C_r
7	2/23/78	5-1	1.0	1.0[2]	1.00	3.88	3.88	17.1[6]
		5-5	1.01	1.0	0.99	0.57	0.57	2.6
		6-2	0.625	1.0	1.60	1.65	2.65[4]	11.8
		6-4	0.957	1.0	1.04	1.52	1.59[4]	7.2
	2/24/78	5-1	0.719	1.0[2]	1.39	3.75	5.21	23.7
		5-5	0.817	1.0	1.22	0.71	0.86[4]	4.0
		5-9	0.988	1.0	1.01	1.90	1.91[4]	8.9
		5-10	0.744	1.0	1.34	4.19	5.61[4]	26.0
		6-4	0.682	1.0	1.47	1.79	2.63[4]	12.0
		6-6	0.604	1.0	1.66	0.95	1.57[4]	5.3
	2/27/78	5-1	0.865	1.0[2]	1.16	2.23	2.58	11.7
		6-6	0.749	1.0	1.34	0.73	0.98[4]	4.5
9	9/20/76	1A[3]	1.064	1.05	0.99	5.24	5.17	37.7[7]
	9/21/76	1B	0.802	1.0[1]	1.25	2.17	2.71	17.8
	9/22/76	1A	0.03	0.843	28.1	0.05	1.36	10.35
10	11/10/76	1	0.660	1.04	1.58	1.97	3.11	17.23[7]
		3[3]	1.368	1.04	0.76	3.54	2.69	15.97
		4[3]	1.061	1.04	0.98	3.31	3.24	19.57
		5	0.934	1.04	1.11	4.07	4.52	27.55
		6	0.817	1.04	1.27	3.23	4.10	25.11
		7	0.698	1.04	1.49	1.78	2.65	16.42
		8	0.659	1.04	1.58	4.45	7.04	43.35
		9	0.721	1.04	1.44	4.69	6.76	41.81
		10	0.511	1.04	2.04	0.58	1.17	7.20
		11	0.933	1.04	1.12	4.46	4.99	30.68
		12[3]	0.856	1.04	1.22	2.58	3.15	18.80
		14	0.647	1.04	1.61	1.92	3.08	19.37

Table 3-2. TEST DATA FOR SUBMERGED LOADING--NORMAL SERVICE (Continued)

Test Number	Test Date	Run Number	$(V/L)_r$	$(V/L)_p$	F factor	$(M/L)_r$ (lb/10³ gal)	$(M/L)_p$ (lb/10³ gal)	C_r
10	11/11/76	1	0.873	1.02	1.17	0.39	0.46	2.78
		2	1.051	1.02	0.97	4.19	4.07	24.92
		3[3]	1.016	1.02	1.00	2.69	2.71	16.55
		4[3]	1.126	1.02	0.91	1.18	1.07	6.51
		5[3]	1.096	1.02	0.93	4.81	4.47	27.21
		6	1.044	1.02	0.98	3.03	2.96	17.95
		7[3]	1.00	1.02	1.02	3.87	3.94	24.11
		8	1.049	1.02	0.97	2.01	1.95	11.97
		9[3]	0.950	1.02	1.07	2.79	2.98	18.41
		10[3]	0.755	1.02	1.35	1.11	1.49	9.20
		11[3]	1.105	1.02	0.92	3.80	3.51	21.46
		12	0.976	1.02	1.04	3.51	3.67	22.45
		13[3]	0.791	1.02	1.29	3.09	3.99	24.45
	11/12/76	1	1.076	1.03	0.96	0.58	0.56	3.25
		2	0.834	1.03	1.24	1.68	2.09	12.20
		3	0.736	1.03	1.40	1.82	2.54	15.00
		4	0.866	1.03	1.19	0.93	1.10	6.50
		5	0.778	1.03	1.32	2.23	2.94	17.2
		6[3]	0.987	1.03	1.04	0.96	1.00	5.80
		8	1.056	1.03	0.98	2.84	2.77	16.30
		9	1.029	1.03	1.00	1.05	1.05	6.20
		10	0.940	1.03	1.10	0.84	0.92	5.80
		11	0.559	1.03	1.84	0.88	1.62	9.60
12	9/26/78	5[3]	1.00	0.915	0.915	3.51	3.21	16.5[6]
		6[3]	1.00	0.915	0.915	3.51	3.21	16.5
		7[3]	1.01	0.915	0.91	2.43	2.21	11.3
		9[3]	0.983	0.915	0.93	2.38	2.21	11.8
		10[3]	0.964	0.915	0.95	3.35	3.18	16.5

Table 3-2. TEST DATA FOR SUBMERGED LOADING--NORMAL SERVICE (Continued)

Test Number	Test Date	Run Number	$(V/L)_r$	$(V/L)_p$	F factor	$(M/L)_r$ (lb/10³ gal)	$(M/L)_p$ (lb/10³ gal)	C_r
12	9/26/78	13[3]	1.07	0.915	0.88	2.29	2.02	10.2
		15[3]	0.890	0.915	1.03	3.40	3.50	18.9
		21	0.994	0.915	0.92	4.41	4.06	
	9/27/78	7[3]	0.846	0.953	1.13	6.15	6.95[4]	34.5
		10[3]	1.05	0.953	0.91	2.23	2.03	10.4
		13[3]	0.953	0.953	1.0	1.21	1.21	6.1
		15[3]	0.929	0.953	1.03	4.50	4.63	23.8
		17	1.23	0.953	0.77	6.46	5.01	25.9
		18[3]	0.998	0.953	0.96	4.92	4.72	23.6
		19[3]	1.03	0.953	0.93	2.32	2.15	11.1
		24[3]	0.888	0.953	1.07	2.93	3.14	16.4
	9/28/78	6[3]	1.40	1.06	0.76	9.61	7.31	33.9
		7[3]	0.903	1.06	1.22	2.87	3.50	16.0
14	12/11/74	6-1	0.622	1.0[1]	1.61	2.40	3.86	24.0[7]
		6-3	0.162	1.0	6.17	0.49	3.02	19.5
		6-4	0.651	1.0	1.54	2.06	3.17	27.0
		6-5	0.026	1.0	38.5	0.12	4.62	29.5
		6-6	0.005	1.0	200.0	0.02	4.00	23.0
		6-7	0.016	1.0	62.5	0.07	4.38	29.5
		6-8	0.009	1.0	111.0	0.004	0.44	31.5
		8-1	0.331	1.0	3.02	0.70	2.11	12.8
		8-2	0.497	1.0	2.01	0.32	0.64	4.0
		8-3	0.625	1.0	1.60	1.77	2.82	17.8
		8-4	0.260	1.0	3.85	0.58	2.23	14.0
		8-5	0.580	1.0	1.72	1.16	2.01	12.5
		8-6	0.332	1.0	3.01	0.47	1.41	8.9
		8-7	0.564	1.0	1.77	0.83	1.48	9.3
		8-8	0.527	1.0	1.90	0.68	1.28	8.0
		8-9	0.306	1.0	3.27	0.33	1.08	6.7
		8-10	0.369	1.0	2.71	0.32	0.88	5.5
		8-12	0.123	1.0	8.13	0.56	4.52	28.3

Table 3-2. TEST DATA FOR SUBMERGED LOADING--NORMAL SERVICE (Continued)

Test Number	Test Date	Run Number	$(V/L)_r$	$(V/L)_p$	F factor	$(M/L)_r$ (lb/10³ gal)	$(M/L)_p$ (lb/10³ gal)	C_r
14	12/12/74	6-1	0.045	0.847	18.8	0.21	3.86	28.5
		6-2	0.355	0.847	2.39	1.68	4.01	29.5
		6-3[3]	0.863	0.847	0.98	3.99	3.92	28.5
		6-4[3]	0.964	0.847	0.88	4.88	4.30	31.5
		6-5	0.065	0.847	13.0	0.33	4.24	31.5
		6-6	0.222	0.847	3.82	1.34	5.12	38.0
		6-7	0.238	0.847	3.60	1.06	3.81	28.0
		6-8	0.614	0.847	1.40	2.87	4.02	29.5
		6-9	0.433	0.847	1.96	2.16	4.24	31.5
		8-1	0.344	0.847	2.46	0.76	1.88	13.8
		8-2	0.340	0.847	2.49	0.37	0.92	6.7
		8-3	0.718	0.847	1.18	1.52	1.80	13.1
		8-4	0.577	0.847	1.47	1.71	2.51	18.6
		8-5	0.177	0.847	4.79	0.07	0.34	2.5
		8-6[3]	0.730	0.847	1.16	1.58	1.83	13.7
		8-7	0.773	0.847	1.10	2.24	2.47	18.3
		8-8	0.223	0.847	3.80	0.61	2.32	17.6
		8-9	0.493	0.847	1.72	1.31	2.25	17.0
		8-10	0.376	0.847	2.25	1.38	3.11	23.2
16	2/20/78	5	0.691	1.0[2]	1.45	2.47	3.58	16.8[6]
		6	0.863	1.0	1.16	2.65	3.07[4]	14.3
		9	0.692	1.0	1.45	2.49	3.61	16.8
		11	0.643	1.0	1.56	1.74	2.72[4]	12.7
	2/21/78	2	0.809	1.0[2]	1.24	4.78	5.93	27.2
17	5/2/78	2	0.320	1.0[2]	3.12	0.49	1.52	7.50[6]
		3	0.285	1.0	3.51	0.27	0.93[4]	4.70
		4	0.591	1.0	1.69	0.79	1.34[4]	6.70
	5/3/78	3	0.990	1.0[2]	1.01	4.12	4.16	20.5
		4	0.800	1.0	1.25	3.26	4.08	20.5

Table 3-2. TEST DATA FOR SUBMERGED LOADING--NORMAL SERVICE (Continued)

Test Number	Test Date	Run Number	$(V/L)_r$	$(V/L)_p$	F factor	$(M/L)_r$ (lb/10³ gal)	$(M/L)_p$ (lb/10³ gal)	C_r
17	5/3/78	6	1.04	1.0	0.96	4.17	4.00	20.5
		7	0.491	1.0	2.04	0.60	1.21[4]	6.20
	5/4/78	1	0.820	1.0[2]	1.22	2.40	2.93	14.6
		2	0.820	1.0	1.22	2.40	2.93	14.0
		3	0.925	1.0	1.08	0.97	1.05[4]	5.1
		4	0.504	1.0	1.98	1.59	3.14	15.6
		7	0.783	1.0	1.27	2.32	2.94	14.6
18	8/2/78	2	0.605	0.936	1.55	2.76	4.27	22.0[6]
		3	0.881	0.936	1.06	3.90	4.14	21.7
		4	0.918	0.936	1.02	4.76	4.86	25.0
		5	0.703	0.936	1.33	2.91	3.87	20.0
		6	0.936	0.936	1.00	2.76	2.76[4]	14.5
		7	0.748	0.936	1.25	2.93	3.67[4]	19.2
		8	0.586	0.936	1.60	4.19	6.70	35.2
		9	0.903	0.936	1.04	4.94	5.14	26.6
		10	0.666	0.936	1.41	2.93	4.13[4]	21.9
		11[3]	0.891	0.936	1.05	3.13	3.29[4]	17.1
		12[3]	0.981	0.936	0.95	4.56	4.35	22.5
		14	0.602	0.936	1.56	4.43	6.91	36.1
		16	0.960	0.936	0.97	4.15	4.04	20.9
		20	0.785	0.936	1.19	4.08	4.85	25.7
		21	0.846	0.936	1.11	4.10	4.55	23.8
		24	0.935	0.936	1.00	4.52	4.52	31.4
		25	0.893	0.936	1.05	7.94	8.33	43.7
		26	0.778	0.936	1.20	6.33	7.59	40.6
	8/3/78	1	0.971	1.34	1.38	5.23	7.21	26.5
		2	0.838	1.34	1.60	2.67	4.27	16.0
		4[3]	1.93	1.34	0.69	5.66	3.93	14.5
		6[3]	1.06	1.34	1.26	8.31	10.47	38.5

Table 3-2. TEST DATA FOR SUBMERGED LOADING--NORMAL SERVICE (Continued)

Test Number	Test Date	Run Number	$(V/L)_r$	$(V/L)_p$	F factor	$(M/L)_r$ (lb/10³ gal)	$(M/L)_p$ (lb/10³ gal)	C_r
18	8/3/78	8	0.901	1.34	1.49	3.26	4.86[4]	18.0
		9	0.532	1.34	2.52	3.24	8.17	30.5
		10	0.906	1.34	1.48	4.34	6.43	23.7
		11	0.939	1.34	1.43	4.76	6.81	25.0
		12	0.957	1.34	1.40	8.71	12.19	45.2
		14	0.894	1.34	1.50	5.49	8.23	30.5
		17	0.257	1.34	5.21	1.90	9.88	36.8
		19	0.776	1.34	1.73	3.46	5.99	22.6
		21[3]	1.10	1.34	1.22	9.15	11.16	42.0
		23	1.09	1.34	1.23	7.08	8.71	32.6
	8/4/78	1	1.10	1.11	1.01	6.11	6.17	27.5
		2	1.01	1.11	1.10	7.30	8.03	35.0
		4[3]	1.14	1.11	0.97	5.47	5.33	23.5
		6[3]	1.07	1.11	1.04	7.43	7.73	34.0
		7	0.361	1.11	3.08	2.60	8.01	38.5
		17	0.942	1.11	1.18	4.76	5.62	25.0
		18	1.14	1.11	0.97	8.29	8.07	36.0
		19	0.933	1.11	1.19	5.58	6.64	29.7
		20	0.833	1.11	1.33	3.59	4.78[4]	21.5
		23	0.985	1.11	1.13	5.25	5.93	26.4
		25	1.11	1.11	1.00	5.60	5.60	25.3
19	9/21/78	2	0.835	1.05	1.26	6.06	7.64	34.5[6]
		4	0.989	1.05	1.06	5.95	6.31[4]	28.1
		5	1.07	1.05	0.98	7.61	7.45	34.7
		6	0.660	1.05	1.59	4.06	6.45	30.0
		9[3]	0.768	1.05	1.37	3.99	5.47	38.5
		12	1.01	1.05	1.04	6.97	7.25	33.8
		14	1.27	1.05	0.83	13.14	10.91	51.5
		16	1.15	1.05	0.91	8.40	7.64	36.5
		17[3]	0.910	1.05	1.15	10.80	12.42	59.2
		18	0.911	1.05	1.15	8.53	9.81	47.5

Table 3-2. TEST DATA FOR SUBMERGED LOADING--NORMAL SERVICE (Continued)

Test Number	Test Date	Run Number	$(V/L)_r$	$(V/L)_p$	F factor	$(M/L)_r$ (lb/10³ gal)	$(M/L)_p$ (lb/10³ gal)	C_r
20	2/1/78	2	0.831	1.0[2]	1.20	0.30	0.35[4]	1.6[6]
		4	0.695	1.0	1.44	0.59	0.85[4]	3.9
		5	0.900	1.0	1.11	1.65	1.84[4]	8.4
		7	0.819	1.0	1.22	1.71	2.08[4]	9.7
		8	0.578	1.0	1.73	0.41	0.70	3.2
		9	0.138	1.0	7.25	0.08	0.60[4]	2.6
		11	0.446	1.0	2.24	0.65	1.46[4]	6.7
		13	0.778	1.0	1.29	3.75	4.84[4]	22.0
		14	0.841	1.0[2]	1.19	3.68	4.38[4]	2.0
	2/2/78	2	0.763	1.0	1.31	0.11	0.15[4]	0.67
		4	0.742	1.0	1.35	0.54	0.73	3.3
		5	0.723	1.0	1.38	0.50	0.68[4]	8.7
		10	1.40	1.0	0.71	0.30	0.21[4]	1.0
		14	0.647	1.0	1.55	0.28	0.44	2.0
		17	0.719	1.0[2]	1.39	1.73	2.40	11.0
	3/6/78	1	0.644	1.0	1.55	2.56	3.96[4]	18.8
		2	1.09	1.0	0.92	3.88	3.57[4]	16.5
		3	0.812	1.0	1.23	2.29	2.82	13.2
		6	0.936	1.0[2]	1.07	3.88	4.15[4]	19.1
	3/7/78	8	0.759	1.0	1.32	2.23	2.94	13.6

NOTES FOR TABLES 3-1 and 3-2

1. Measurements indicated no vapor-tight tank trucks on this test day; therefore, value for all runs on this day is assumed to be 1.0.

2. No tank truck leakage measurements made on this test day; therefore, value for all runs on this day is assumed to be 1.0.

3. Tank truck in this test run was determined to be vapor-tight.

4. Product carried on previous load was unknown or was other than gasoline; therefore, this test run was not included in the calculations.

5. Mole percent as propane (applies to all runs in this test).

6. Volume percent as butane (applies to all runs in this test).

7. Volume percent as propane (applies to all runs in this test).

DEFINITIONS

$(V/L)_r$ = Volume of air-VOC mixture returned to processing unit per volume of liquid dispensed.

$(V/L)_p$ = Potential vapor/liquid volume ratio, assuming no vapor leakage losses.

F Factor = $(V/L)_p \div (V/L)_r$, an adjustment factor to account for vapor leakage.

$(M/L)_r$ = VOC mass returned to processing unit per volume of liquid dispensed (uncontrolled emissions).

$(M/L)_p = F \times (M/L)_r$, adjusted VOC mass emissions including emissions from tank trucks (emission factor).

C_r = Concentration of VOC in mixture returned to processing unit (volume percent as propane or butane; Vol. percent propane = 1.32 x vol. percent butane).

the emission factor currently in use for splash loading--normal service; however, it very nearly agreed with the splash loading--balance service factor. Regardless, this one emission test did not constitute an adequate data base by which to either confirm or revise the emission factors currently in use.

Test results excluded from use in emission factor determination were as follows:

(1) Test series that were reported unclearly as to whether splash or submerged loading was employed;

(2) Test runs that did not indicate whether vapor balancing (Stage I vapor recovery) was used at the bulk plants or service stations to which the tank trucks made their deliveries;

(3) Test runs for which the previous product load was not listed for individual tank trucks loading at the terminal.

Data in categories (1) and (2) were not included in Tables 3-1 and 3-2. Data in the third category were included in Table 3-2, but not in the calculation of averages.

3.1.2 Calculation of Data Base

In the emission tests from which tank truck VOC emission data were derived, the quantity of VOC vapors expelled from tank trucks into a vapor collection system was measured at the inlet to a vapor processing unit. Since most tank trucks are known to leak vapors during loading, from dome covers, pressure-vacuum (P-V) vents, and other leakage points, some fraction of the expelled vapors are lost directly to the atmosphere during loading. When air-vapor mixture leakage from tank trucks occurs, the quantity of VOC actually recovered

by the vapor collection system is less than the amount potentially recoverable in a leak-free system.

In calculating the total amount of VOC emitted during each loading, the runs during which no leaks were detected by combustible gas detector measurements were isolated, and the potential volumetric recovery was calculated for just these runs. For the purposes of these calculations, a leak was defined as occurring whenever a reading on the detector exceeded 100 percent of the lower explosive limit, a definition suggested in the CTG for control of leaks from tank trucks and vapor collection systems.[9] The average potential volumetric recovery, $(V/L)_p$, was calculated for each testing day, to account for the particular conditions at that terminal on that day. The run-by-run values which make up this parameter are weighted in proportion to the amount of gasoline loaded during each run, and the parameter reflects the average gas volume-to-liquid volume ratio in the leak-free system. The $(V/L)_p$ parameter serves as a baseline against which to adjust each loading to account for vapor leakage. As seen in Tables 3-1 and 3-2, values can be less than, equal to, or greater than 1.0.

The actual measured volumetric recoveries, $(V/L)_r$, for each run are highly variable and can also be less than, equal to, or greater than 1.0. Values less than 1.0 can usually be attributed to system leakage, but may be due to vapor condensation within the system. Recoveries which exceed 1.0 are due to vapor growth, which may result from certain temperature and pressure conditions in the tank trucks and vapor return lines.

An adjustment, or F factor, was calculated for each test run (tank truck loading) in order to account for leakage. This factor was calculated using the formula:

$$F \text{ factor} = (V/L)_p \div (V/L)_r.$$

Actual measured mass emissions, $(M/L)_r$, in each run were multiplied by the corresponding F factor to produce a potential, or total emission value, $(M/L)_p$, which represents the total emission factor for the loading. It can be seen from this expression that the smaller $(V/L)_r$ is in relation to $(V/L)_p$ (indicating greater leakage), the larger the F factor becomes, and the more adjustment is applied to the measured value.

The VOC mass returned to the vapor processor was calculated using measured values for gas volume and hydrocarbon concentration. When divided by the volume of liquid loaded in each test run, individual values of $(V/L)_r$ and $(M/L)_r$ are generated.

Section 3.1.3 provides an example of the calculations used in generating the emission factors from these test data.

3.1.3 Sample Calculation

The 22 tests performed by EPA at controlled bulk terminals between 1973 and 1978 followed, with occasional minor exceptions, the procedures developed by EPA-OAQPS as outlined in the CTG document for terminals.[3] The principal measured quantities in this method are hydrocarbon concentration returned, C_r, air-vapor mixture volume returned, V_r, and volume of liquid product loaded, L. The methods being proposed in accompaniment with the NSPS contain some refinements, but are essentially the same as the CTG methods. Calculations are performed as in the sample below.

Given: C_r = 40.0 vol. percent as propane
= 4.00×10^5 ppmv,

V_r = 14,400 liters
= 14.4 m^3, and

L = 18,000 liters
= 18.0 m^3.

Then: $M_r = 10^{-6} K V_r C_r$
$= 10^{-6}(1.83 \times 10^6 \text{ mg/m}^3)(14.4 \text{ m}^3)(4.00 \times 10^5 \text{ ppmv})$
$= 10.5 \times 10^6$ mg,

And: $$(M/L)_r = \frac{10.5 \times 10^6 \text{ mg}}{18{,}000 \text{ liters}}$$

$$= 586 \text{ mg/liter.}$$

Also: $$(V/L)_r = \frac{14.4 \text{ m}^3}{18.0 \text{ m}^3} = 0.800 \text{ m}^3/\text{m}^3.$$

In all EPA tests, measurements were taken as part of an evaluation of a vapor collection and processing system. Uncontrolled tank truck emissions were taken to be the mass of VOC returned to the processor for each unit volume of product loaded. However, most tank trucks leak some of the vapors to the atmosphere during loading, and these cannot be quantified. Thus, by monitoring for vapor leakage during loading, the measured emissions can be adjusted to represent the total emissions from the tank truck. To calculate these potential emissions, the average vapor volume/liquid ratio is calculated for loadings of vapor-tight tank trucks on a particular test day. This quantity is

then divided by the measured vapor/liquid ratio measured in each test run, to produce a leak adjustment factor for each run. If no leakage measurements were made on a given test day, or if no vapor-tight tanks were found, then the average potential vapor/liquid ratio is assumed equal to 1.0. The leak factor is multiplied by the calculated measured mass/volume ratio to produce the quantity which represents the loading emission factor used in this revision effort. A sample calculation is shown below.

Given: $(V/L)_r$ = measured vapor/liquid ratio, Test Run A on Day 1

= 0.800 m^3/m^3, and

$(V/L)_p$ = average vapor/liquid ratio for all vapor-tight trucks on Day 1

= 1.20 m^3/m^3.

Then: $F = (V/L)_p \div (V/L)_r = 1.50$.

Also: $(M/L)_r$ = calculated mass/liquid ratio for Test Run A

= 586 mg/liter.

The emission factor is then:

$(M/L)_p = F \times (M/L)_r$

= loading emission factor for Test Run A

= 1.50 x 586 mg/liter

= 879 mg/liter.

Individual (V/L) values are weighted by the volume of product loaded during each test run in order to calculate $(V/L)_p$.

3.2 METHODS OF DATA REDUCTION

3.2.1 Selection of Alternative Methods

After reviewing the data which were not excluded from Tables 3-1 and 3-2 for reasons previously stated, three averaging methods were considered, each utilizing a different data base to determine the most representative emission factor. The three averaging methods were:

(1) Arithmetic mean of $(M/L)_p$ based on all test runs;

(2) Arithmetic mean of $(M/L)_p$ based on test runs for which $(V/L)_p$ could be calculated from measured parameters;

(3) Arithmetic mean of $(M/L)_p$ based on data associated with loadings of vapor-tight tank trucks only.

In examining the complete data base (281 balance service runs and 183 normal service runs), it was discovered that there were many test days for which the potential volumetric recovery parameter $(V/L)_p$ could not be calculated. No tank truck leakage measurements were taken in Test Nos. 2, 4, 5, 7, 16, 17, or 20. Individual test days from some other tests also had no leakage measurements available. Therefore, in order to adjust the measured emissions to account for leakage, the value of $(V/L)_p$ had to be assumed. A nominal value of 1.0 was assumed, even though the actual value of this parameter is rarely 1.0. So Method 1 contains a degree of uncertainty due to this assumption, and is less desirable than a method into which this uncertainty has not been introduced.

Under the second method, only test runs occurring on days for which the actual value of $(V/L)_p$ could be calculated were considered in the emission factor estimation process. Adjustment for leakage is

still required as in Method 1, but the adjustment more closely corresponds to conditions during each test. The data base under Method 2 consists of 118 balance service runs and 122 normal service runs.

The third method requires no adjustment of measured results, because only loadings of vapor-tight tank trucks (as determined during each test run) are considered in the data base. This method is preferable where the body of data is sufficiently large for statistically valid averages to be generated. In the tests which composed the initial data base, 30 balance service runs and 37 normal service runs were found by combustible gas detector measurements to be vapor-tight.

The calculated values of $(V/L)_p$ in Tables 3-1 and 3-2 range from 0.843 to 1.34. If the value of $(V/L)_p$ were assumed to be 1.0 in these two cases, the F factor, and hence the emission factor, could be in error by up to 25 percent. This degree of uncertainty is considered unacceptably large if an alternate data base of sufficient size is available from which more reliable results can be derived.

The quantity of data in Method 2 is considered to represent a sufficient cross-section of various terminal conditions to permit an emission factor evaluation to be undertaken. Data on balance service factors were taken from eight terminal tests, and data on normal service factors came from seven tests. Since potential volumetric recoveries were calculated in all cases, the uncertainty inherent in Method 1 is not a factor in Method 2. Since the method of adjusting for vapor leakage is considered a valid (and necessary) means of calculating representative total emissions, Method 2 with an adequate data base can be used to generate emission averages.

The size of the data base in Method 3 is not considered sufficient to justify using only test runs on vapor-tight trucks in the calculation of average emission factors. The number of runs on vehicles in balance service, for example, represents only the total loadings expected at a medium size terminal in 1 day.

Considering the shortcomings of Methods 1 and 3 (assumption of parameter values and small data base, respectively), Method 2 was selected for calculating the emission factor averages used in this evaluation effort.

3.2.2 Results of Alternative Methods

Arithmetic means of the individual emission factor values were calculated from all three data bases considered in this analysis. This was done to assess the impacts on the final emission factors of various data bases, and to compare adjusted results in Methods 1 and 2 with the results from vapor-tight runs in Method 3.

The comparison values (current emission factors) are contained in Table 4.4-3 of AP-42. The emission factor for submerged loading--balance service of gasoline is 8 lb/10^3 gallons transferred (960 mg/liter). The factor shown for submerged loading--normal service is 5 lb/10^3 gallons transferred (600 mg/liter). As discussed in Section 1.3, these current factors are derived from predictive equations which utilize certain average physical properties of loaded product as well as a limited amount of emission data collected in field tests.

Tables 3-3 and 3-4 present the mean balance and normal service emission factor in each test considered under each of the three data bases, as well as the lowest and highest values occurring in each

Table 3-3. DATA SUMMARY FOR THREE CALCULATION METHODS, SUBMERGED LOADING--BALANCE SERVICE

Emission Factor, lb/10^3 gal (mg/liter)											
Method 1[a]				Method 2[b]				Method 3[c]			
Test No.	Lowest Value	Highest Value	Arithmetic Mean	Test No.	Lowest Value	Highest Value	Arithmetic Mean	Test No.	Lowest Value	Highest Value	Arithmetic Mean
1	4.01(480)	10.6(1,270)	8.35(1,000)	3	2.89(346)	8.84(1,060)	6.72(805)	3	5.71(684)	7.83(938)	7.20(863)
2	2.96(355)	3.81(456)	3.26(391)	6	0.31(37)	5.56(666)	3.35(401)	6	0.31(37)	0.31(37)	0.31(37)
3	2.89(346)	8.84(1,060)	6.72(805)	9	3.61(432)	6.80(815)	4.99(598)	9	3.61(432)	5.52(661)	4.57(547)
5	2.88(345)	7.83(938)	5.83(698)	10	3.44(412)	5.80(695)	4.72(565)	10	3.92(470)	5.80(695)	5.15(617)
6	0.31(37)	7.94(951)	4.25(509)	12	2.25(270)	10.3(1,230)	6.90(827)	12	4.97(595)	10.3(1,230)	6.95(833)
7	1.62(194)	6.56(786)	4.66(558)	18	5.76(690)	14.1(1,730)	10.1(1,210)	19	10.2(1,220)	36.8(4,410)	19.3(2,310)
9	3.61(432)	6.80(815)	5.11(612)	19	9.38(1,120)	36.8(4,410)	14.0(1,670)	21	10.8(1,290)	12.3(1,470)	11.5(1,370)
10	3.44(412)	5.80(695)	4.72(565)	21	4.15(497)	14.3(1,710)	11.3(1,350)				
12	2.25(270)	10.3(1,230)	6.90(827)								
16	2.67(320)	6.17(739)	5.15(617)								
17	2.42(290)	7.56(906)	5.86(702)								
18	5.76(690)	14.1(1,730)	10.1(1,210)								
19	9.38(1,120)	36.8(4,410)	14.0(1,680)								
20	2.41(289)	7.89(945)	5.06(606)								
21	4.15(497)	14.3(1,710)	11.3(1,350)								

[a]Data base includes all valid test runs from available EPA emission tests.

[b]Data base includes only test runs for which $(V/L)_p$ could be calculated from measured parameters.

[c]Data base includes only test runs in which the loaded tank truck was vapor-tight.

Table 3-4. DATA SUMMARY FOR THREE CALCULATION METHODS, SUBMERGED LOADING--NORMAL SERVICE

Emission Factor, lb/10^3 gal (mg/liter)											
Method 1[a]				Method 2[b]				Method 3[c]			
Test No.	Lowest Value	Highest Value	Arithmetic Mean	Test No.	Lowest Value	Highest Value	Arithmetic Mean	Test No.	Lowest Value	Highest Value	Arithmetic Mean
2	1.04(125)	4.46(534)	3.00(359)	3	6.36(762)	6.81(816)	6.59(789)	9	5.17(619)	5.17(619)	5.17(619)
3	6.36(762)	6.81(816)	6.59(789)	9	1.36(163)	5.17(619)	3.08(369)	10	0.56(67)	4.52(541)	2.77(332)
5	1.99(238)	5.52(661)	3.45(413)	10	0.46(55)	4.99(598)	2.87(344)	12	1.21(145)	7.31(876)	3.19(382)
7	0.57(68)	5.21(624)	3.06(367)	12	1.21(145)	7.31(876)	3.66(438)	14	1.83(219)	4.30(515)	3.35(401)
9	1.36(163)	5.17(619)	3.08(369)	14	0.34(41)	5.12(613)	3.00(359)	18	3.93(471)	11.2(1,340)	7.16(858)
10	0.46(55)	4.99(598)	2.87(344)	18	3.67(440)	12.2(1,460)	6.54(783	19	5.47(655)	12.4(1,490)	8.95(1,070)
12	1.21(145)	7.31(876)	3.66(438)	19	5.47(655)	12.4(1,490)	8.34(999)				
14	0.34(41)	5.12(613)	2.73(327)								
16	3.58(429)	5.93(710)	4.37(524)								
17	1.52(182)	4.16(498)	3.21(385)								
18	3.67(440)	12.2(1,460)	6.54(783)								
19	5.47(655)	12.4(1,490)	8.34(999)								
20	0.44(53)	4.84(580)	2.13(255)								

[a]Data base includes all valid test runs from available EPA emission tests.

[b]Data base includes only test runs for which $(V/L)_p$ could be calculated from measured parameters.

[c]Data base includes only test runs in which the loaded tank truck was vapor-tight.

test. Table 3-5 summarizes these results by showing overall emission factor averages under each data base.

The first trend noted in Table 3-5 is that in all cases the balance service factor is considerably higher than the normal service factor. The balance service factors under Methods 1, 2, and 3 are 65, 59, and 54 percent higher, respectively, than the corresponding normal service factors. This compares closely with the 60 percent differential (960 vs 600 mg/liter) between the current AP-42 balance and normal service factors.

Most of the calculated factors are lower than the current factors in AP-42. Balance service factors are 16, 3 and 2 percent lower under Methods 1, 2, and 3, respectively, than the current factors. Normal service factors under Methods 1 and 2 are 19 and 3 percent lower, respectively, than current factors. Under Method 3, however, the average normal service factor is 2 percent higher than the current factor.

The mean emissions calculated under Method 3 are higher than those calculated under Method 2, which are in turn higher than the mean in Method 1. Assuming that the vapor-tight tank trucks considered in Method 3 represent the ideal test case for determining representative average emission factors, the other two methods have produced slightly underestimated emission averages in these tests.

A breakdown of the data by the statistical parameters of mean, standard deviation, and 95 percent confidence interval is presented in Tables 3-6, 3-7, and 3-8.

Table 3-5. EMISSION FACTOR AVERAGES FOR THREE CALCULATION METHODS - GASOLINE LOADING INTO TANK TRUCKS

Emission Source	Current AP-42 Emission Factor (Table 4.4-3)	Method 1		Method 2		Method 3	
		Average Emissions[a]	No. of Runs	Average Emissions[b]	No. of Runs	Average Emissions[c]	No. of Runs
Submerged Loading--balance service	8 lb/10^3 gal (960 mg/liter)	6.75 lb/10^3 gal (809 mg/liter)	281	7.75 lb/10^3 gal (928 mg/liter)	118	7.84 lb/10^3 gal (940 mg/liter)	30
Submerged Loading--normal service	5 lb/10^3 gal (600 mg/liter)	4.08 lb/10^3 gal (489 mg/liter)	183	4.87 lb/10^3 gal (583 mg/liter)	122	5.10 lb/10^3 gal (611 mg/liter)	37

[a]Arithmetic mean based on all valid test runs.

[b]Arithmetic mean based only on test runs for which $(V/L)_p$ could be calculated from measured parameters.

[c]Arithmetic mean based only on test runs in which the loaded tank truck was vapor-tight.

Table 3-6. EMISSION FACTOR STATISTICAL BREAKDOWN--CALCULATION METHOD 1[a]

Balance Service					Normal Service				
Test No.	No. of Runs	Arithmetic Mean, lb/10³ gal(mg/l)	Standard Deviation, lb/10³ gal	95 Percent Confidence Interval, lb/10³ gal(mg/l)	Test No.	No. of Runs	Arithmetic Mean, lb/10³ gal(mg/l)	Standard Deviation, lb/10³ gal	95 Percent Confidence Interval, lb/10³ gal(mg/l)
1	31	8.35(1,000)	1.51	7.80-8.90(934-1,070)	2	8	3.00(359)	1.17	2.02-3.98(242-477)
2	3	3.26(391)	0.48	2.07-4.45(248-533)	3	2	6.59(789)	0.32	3.71-9.47(444-1,130)
3	38	6.72(805)	1.19	6.33-7.11(758-852)	5	9	3.45(413)	1.08	2.62-4.28(314-513)
5	17	5.83(698)	1.32	5.15-6.51(617-780)	7	4	3.06(367)	1.98	0-6.21(0-744)
6	29	4.25(509)	1.90	3.53-4.97(423-595)	9	3	3.08(369)	1.93	0-7.87(0-943)
7	37	4.66(558)	1.33	4.22-5.10(506-611)	10	35	2.87(344)	1.58	2.33-3.41(279-409)
9	5	5.11(612)	1.29	3.51-6.71(420-804)	12	17	3.66(438)	1.66	2.81-4.51(337-540)
10	4	4.72(565)	1.22	2.78-6.66(333-798)	14	37	2.73(327)	1.36	2.28-3.18(273-381)
12	22	6.90(827)	1.65	6.17-7.63(739-914)	16	3	4.37(524)	1.35	1.02-7.72(122-925)
16	26	5.15(617)	1.10	4.71-5.59(564-670)	17	8	3.21(385)	0.88	2.47-3.95(296-473)
17	7	5.86(702)	1.81	4.19-7.53(502-902)	18	38	6.54(783)	2.16	5.83-7.25(698-869)
18	8	10.1(1,210)	2.58	7.94-12.3(951-1,470)	19	9	8.34(999)	2.24	6.62-10.1(793-1,210)
19	8	14.0(1,670)	9.32	6.17-21.7(739-2,610)	20	10	2.13(255)	1.72	0.90-3.36(108-403)
20	22	5.06(606)	1.51	4.39-5.73(526-686)					
21	24	11.3(1,350)	2.15	10.4-12.2(1,240-1,460)					

[a]Data base includes all valid test runs from available EPA emission tests.

Table 3-7. EMISSION FACTOR STATISTICAL BREAKDOWN--CALCULATION METHOD 2[a]

Balance Service					Normal Service				
Test No.	No. of Runs	Arithmetic Mean, lb/10³ gal(mg/l)	Standard Deviation, lb/10³ gal	95 Percent Confidence Interval, lb/10³ gal(mg/l)	Test No.	No. of Runs	Arithmetic Mean, lb/10³ gal(mg/l)	Standard Deviation, lb/10³ gal	95 Percent Confidence Interval, lb/10³ gal(mg/l)
3	38	6.72(805)	1.19	6.33-7.11(758-852)	3	2	6.59(789)	0.32	3.71-9.47(444-1,130)
6	14	3.35(401)	1.51	2.48-4.22(297-506)	9	2	3.27(392)	2.69	0-27.4(0-3,290)
9	4	4.99(598)	1.46	2.67-7.31(320-876)	10	35	2.87(344)	1.58	2.33-3.41(279-409)
10	4	4.72(565)	1.22	2.78-6.66(333-798)	12	17	3.66(438)	1.66	2.81-4.51(337-540)
12	22	6.90(827)	1.65	6.17-7.63(739-914)	14	19	3.00(359)	1.30	2.37-3.63(284-435)
18	8	10.1(1,210)	2.58	7.94-12.3(951-1,470)	18	38	6.54(783)	2.16	5.83-7.25(698-869)
19	8	14.0(1,670)	9.32	6.17-21.7(739-2,600)	19	9	8.34(999)	2.24	6.62-10.1(793-1,210)
21	20	11.3(1,350)	2.36	10.2-12.4(1,220-1,490)					

[a]Data base includes only test runs for which $(V/L)_p$ could be calculated from measured parameters.

Table 3-8. EMISSION FACTOR STATISTICAL BREAKDOWN--CALCULATION METHOD 3[a]

Balance Service					Normal Service				
Test No.	No. of Runs	Arithmetic Mean, lb/10³ gal(mg/l)	Standard Deviation, lb/10³ gal	95 Percent Confidence Interval, lb/10³ gal(mg/l)	Test No.	No. of Runs	Arithmetic Mean, lb/10³ gal(mg/l)	Standard Deviation, lb/10³ gal	95 Percent Confidence Interval, lb/10³ gal(mg/l)
3	12	7.20(863)	0.65	6.39-8.01(766-960)	9	1	5.17(619)	--	--
6	1	0.31(37)	--	--	10	13	2.77(332)	1.22	2.03-3.51(243-420)
9	2	4.57(547)	1.35	2.37-6.77(284-811)	12	12	3.19(382)	1.58	2.19-4.19(262-502)
10	3	5.15(617)	1.07	3.75-6.55(449-785)	14	3	3.35(401)	1.33	0.05-6.65(6-797)
12	5	6.95(833)	2.11	4.87-9.03(583-1,080)	18	6	7.16(858)	3.13	3.87-10.4(464-1,250)
19	4	17.1(2,050)	13.1	3.37-30.9(404-3,700)	19	2	8.95(1,070)	4.91	0-53.1
21	3	11.4(1,370)	0.75	10.5-12.3(1,260-1,480)					

[a]Data base includes only test runs in which the loaded tank truck was vapor-tight.

3.3 COMPARISON OF RESULTS WITH EXISTING AP-42 FORMULAS

The methods used to calculate the current gasoline loading emission factors in AP-42 were discussed in Section 1.3. These factors are only indirectly based on actual emission measurements, and represent ideal emissions from the loading of gasoline with certain properties (RVP = 10 psia, T = 60°F). The basis for these factors is the ideal gas equation, a theoretical approach which should be verified with actual measured emissions under the range of conditions experienced in practice.

EPA bulk terminal testing was performed under a wide range of atmospheric conditions and gasoline properties. For example, while RVP measurements were not made in the EPA tests, individual gasoline stocks are blended to produce RVP's from approximately 7 to 13. It is not known how closely the average conditions in the EPA tests compare with the conditions assumed in deriving the current emission factors, since these measurements were not made during testing. Thus, a direct comparison between the two sets of results should be approached with caution. While current factors represent a single calculation using a theoretical expression and certain assumed average physical conditions, the results presented here are averages from several actual individual measurements where all of the conditions were not known. For this reason, a one-for-one comparison of results from these two sources is not recommended.

As stated in Section 4.4.2 of AP-42, the loading loss equation estimates emissions with a probable error of ±30 percent. Therefore, current factors should be considered to represent a good approximation

of typical loading examples, and may not correspond to a particular case under consideration. Differentials of only 3 percent, for both balance and normal service emission factors, between Method 2 results and the current factors, are considered excellent verification that the current factors are representative of average emissions over a wide range of conditions. However, it may be preferable in individual situations to calculate emission factors using actual known conditions (product properties and environmental conditions), when these conditions are known to vary significantly from those assumed in deriving the factors in Table 4.4-3 of AP-42.

3.4 CONCLUSIONS

Measurements of emissions during balance service loading were taken in 15 tests at bulk terminals. A total of 281 runs (tank truck loadings) were made, and emissions averaged 6.75 lb/10^3 gal (809 mg/liter). However, only test runs for which the potential gas volume/liquid volume ratio, $(V/L)_p$, could be calculated were used in determining representative emission factors. These 118 runs in 8 tests produced an average of 7.75 lb/10^3 gal (928 mg/liter). This value is well within the 30 percent uncertainty (current factor 8 lb/10^3 gal, or 960 mg/liter) associated with the AP-42 emission equation (see Section 1.3 of this document).

Averages in individual tests ranged from 3.35 lb/10^3 gal (401 mg/liter) in Test No. 6 to 14.0 lb/10^3 gal (1,670 mg/liter) in Test No. 19. Individual test runs produced emissions between 0.31 and 36.8 lb/10^3 gal (37 to 4,410 mg/liter) for the 118 runs.

Measurements of normal service loading emissions were taken in 13 tests. A total of 183 runs were made, averaging emissions of 4.08 lb/10^3 gal (489 mg/liter). Of these runs, 122 in 7 tests were considered representative because $(V/L)_p$ could be calculated. These 122 runs produced an average of 4.87 lb/10^3 gal (583 mg/liter). This value is well within 30 percent of the current factor of 5 lb/10^3 gal (600 mg/liter).

The relatively large variations observed among individual tank truck loadings, even within the same test, are not readily explained because all of the conditions surrounding the loadings were not recorded. This would be impractical in any event, because the tank's history before the loading (i.e., conditions at the unloading points) is a major determining factor in the magnitude of the emissions during a loading. These conditions are not measured during emission tests, and so the condition of the "empty" tank truck is only assumed prior to loadings, depending on whether it is in balance service or normal service. Generally, the same tank truck loading and unloading the same product at the same two points within a short time period (similar environmental conditions) should produce very similar emissions during loadings. However, the several tank trucks at a particular terminal deliver to a variety of drop points at all times of the day. Therefore, the emissions from individual loadings should be expected to vary considerably, and a large sample population is necessary in order for valid conclusions to be drawn concerning representative emission levels. For this reason, Method 2 was selected over Method 3 as the basis for the calculation of the average emission factors for balance and normal service loading.

As discussed in Section 3.3, the average emission factors calculated according to Method 2 are considered a verification of the validity of the current AP-42 factors. Furthermore, since the Method 2 values are less than 5 percent lower than the Method 3 values, the selection of either data base would have no impact on the determination that the current factors should not be revised based on these new test data. When applying these emission factors toward the calculation of VOC loading emissions in an area where the pertinent physical conditions can be estimated with a high degree of confidence, the user should calculate individual factors based on the expressions in AP-42.

4.0 EMISSION FACTOR SUPPORT EMISSION TESTS

4.1 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) conducted 22 emission tests for VOC emissions at controlled bulk gasoline terminals throughout the U.S. between 1973 and 1978. These tests followed, with occasional minor exceptions, the procedure developed by EPA's Office of Air Quality Planning and Standards (OAQPS) as described by the CTG for terminals.[3]

Tests were performed on six types of vapor processors. The types of systems tested are carbon adsorption (CA), Test Nos. 1 through 3; thermal oxidizer (TO), Test Nos. 4 through 7; refrigeration (REF), Test Nos. 8 through 13; compression-refrigeration-absorption (CRA), Test Nos. 14 through 19; and compression-refrigeration-condensation (CRC), Test Nos. 20 and 21. The test data indicate that concentrations at the inlet of the processor (vapors displaced from tank trucks) vary considerably from terminal to terminal. This variation is caused by many factors which can include product temperature, ambient pressure, vapor tightness of tank trucks, loading method, and whether vapor balancing is used at delivery points. Therefore, information on vapor tightness, loading method, balance or normal service, and previous product loaded was necessary in order for these test reports to be used as supporting information in this analysis.

Of the 21 tests used as supporting information, 19 terminals bottom load gasoline and 2 terminals top load gasoline. In addition, at 19 of the terminals tested, gasoline tank trucks served both non-vapor recovery and vapor recovery equipped service stations. At one of the terminals tested (Test No. 14), none of the tank trucks being loaded was making deliveries to a station equipped for vapor recovery during unloading, and at two of the terminals tested (Test Nos. 1 and 6), only tank trucks which had made deliveries to vapor recovery equipped service stations were being loaded.

As discussed in Section 3.1.2, the potential volumetric recovery $(V/L)_p$ is calculated for a particular test day by averaging the $(V/L)_r$ values for all loadings of tank trucks determined to be vapor-tight (by measurements with a combustible gas detector during loading). For this purpose, a vapor-tight truck is defined as one with no leaks exceeding 100 percent of the lower explosive limit. For several of the test days, no vapor-tight trucks are known to have loaded, either because measurements were not taken or because none of the measured trucks was found to be vapor-tight. In these cases, it was assumed that the volume of air-vapor mixture displaced during each truck loading equaled the volume of gasoline loaded (i.e., $(V/L)_p$ was assumed equal to 1.0).

4.2 SUMMARIES OF EPA-CONDUCTED TESTS

The following test summaries contain descriptions of the facilities tested, as well as information about test conditions which might have influenced the test results. The test numbers match the numbers assigned to the tests in the background information document for the proposed

bulk terminal standards.[2] The referenced test reports can be found in the docket of background materials for the development of the bulk gasoline terminals NSPS, OAQPS docket no. A-79-52.

4.2.1 Bulk Terminal Test No. 1

This terminal is a small gasoline loading terminal with a storage capacity of 3,600,000 liters (950,000 gallons) of gasoline and a daily gasoline throughput of 285,000 liters (75,000 gallons). Barges deliver the supply of gasoline to the terminal. Two loading racks employ five bottom-loading positions, with vapor recovery lines leading to an activated carbon adsorption (CA) type vapor recovery unit.

Gasoline tank trucks and trailers loading at this terminal serve retail stations equipped for gasoline vapor recovery. Since no tank trucks monitored for leakage during this test met the vapor tightness requirement, $(V/L)_p$ was set equal to 1.0 for the calculations.

Testing was performed May 25-27, 1977, during 33 tank truck loadings to determine actual VOC emissions, potential VOC emissions, and the vapor recovery efficiency of the system. VOC's generated during bottom loading of tank trucks at the terminal are collected by a vapor line collection system and routed to the carbon adsorption vapor processor. The hydrocarbon concentrations as measured at the inlet to the vapor processing unit (C_r in Table 3-1) were included in the test report only for a few runs and are listed in propane mole percent. Other concentrations not listed were very high due to improper cycling of the processor.

Further details are contained in the emission test report.[7]

4.2.2 Bulk Terminal Test No. 2

Test No. 2 was performed March 1-3, 1978, at a small bulk terminal with an average daily gasoline throughput of 189,000 liters (50,000 gallons). Gasoline is dispensed from one loading rack containing three bottom-load dispensing arms.

Vapors displaced from tank trucks during loading are routed to a vapor holder (premium gasoline storage tank equipped with lifter roof). When a specified capacity is reached, the control system is manually started and the vapors travel to a CA vapor recovery unit.

Gasoline tank trucks and trailers loading at this terminal serve both non-vapor balance and vapor balance equipped service stations. No vapor tightness measurements were performed during this test; therefore, $(V/L)_p$ was assumed to equal 1.0. During the test period, tank trucks returned an average of 0.690 cubic meter of air-vapor mixture for each cubic meter of gasoline pumped. This indicates that the tank trucks were probably not vapor-tight.

During testing, terminal operations were normal, and no instrument problems were reported.

Further details are contained in the emission test report.[10]

4.2.3 Bulk Terminal Test No. 3

This test was conducted at a bulk terminal with an average daily gasoline throughput of approximately 303,000 liters (80,000 gallons). This terminal is the same one described in Test No. 1. At the start of each day, gasoline tank trucks are loaded on a staggered time schedule with half-hour intervals between loadings. Two of the five loading racks at the terminal dispense gasoline and use vapor recovery. Testing was performed on October 24-26, 1978.

Air-vapor mixture displaced during loading is piped to a liquid knockout tank and then passes to a CA vapor recovery unit.

Gasoline tank trucks and trailers loading at this terminal serve both non-vapor balance and vapor balance equipped service stations. Among the 40 tank truck loadings checked, 12 of them were determined to be free of leakage. The corresponding $(V/L)_p$ values were used for calculation of potential emissions.

The test method followed the specified procedure. Total VOC concentrations were measured as volume percent as butane.

Further details are contained in the emission test report.[11]

4.2.4 Bulk Terminal Test No. 5

Test No. 5 was performed January 25-27 and January 30, 1978, at a bulk terminal whose average gasoline throughput is 757,000 liters per day (200,000 gallons per day). Gasoline is dispensed from four bottom loading arms at two loading racks. The air-vapor mixture displaced from tank trucks is directed through a vapor collection system to a liquid knockout tank, and then to a TO type vapor control unit.

No problems with the control unit or test instrumentation were reported during testing. All VOC concentrations were reported as volume percent as butane.

Gasoline tank trucks and trailers loading at this terminal serve both non-vapor balance and vapor balance equipped service stations. Combustible gas detector measurements were not performed during this test; therefore, $(M/L)_p$ was estimated from the volume of incoming gasoline by assuming that the volume of vapors displaced during each truck loading equaled the volume of gasoline loaded (i.e., $(V/L)_p$ was

assumed to equal 1.0). During the test period, tank trucks returned an average of 0.840 cubic meter of air-vapor mixture for each cubic meter of gasoline pumped.

Further details about the test are contained in the emission test report.[12]

4.2.5 Bulk Terminal Test No. 6

At this tank truck gasoline loading terminal the vapors are vented directly to a TO control unit. The terminal is equipped with three gasoline bottom loading rack positions, with regular, premium, and unleaded gasoline loaded at each of these racks. At one loading rack, the tank truck vapor vent line was connected to a turbine meter to measure the volume of vapors vented from the tank truck to the vapor control system. Testing was performed on January 10-12, 1978.

During the test period the terminal was in normal operation and the thermal oxidizer appeared to be operating properly. The daily throughput of gasoline approximated 950,000 liters (250,000 gallons). All trucks were tested for vapor tightness around the hatch covers, relief valves, vapor line connection, and automatic shutoff sensor. Among the 31 tank truck loadings checked, one was determined to be vapor-tight.

Further details are contained in the emission test report.[13]

4.2.6 Bulk Terminal Test No. 7

Testing was conducted February 23, 24, and 27, 1978, at a bulk terminal whose daily gasoline throughput is approximately 1,500,000 liters (400,000 gallons). Gasoline is dispensed from six loading racks through both bottom-loading and top-loading vapor recovery arms.

However, tests were conducted only on the bottom-loading arms. The specified test procedure was followed, and VOC concentrations were measured as volume percent as butane. The thermal oxidizer control unit and other vapor control equipment at the terminal were in good condition.

Gasoline tank trucks and trailers loading at this terminal serve both non-vapor balance and vapor balance equipped service stations. No leak monitoring was performed during this test; therefore, $(V/L)_p$ was assumed to equal 1.0. During the test period, tank trucks returned an average of 0.789 cubic meter of air-vapor mixture for each cubic meter of gasoline pumped. This indicates that many tank trucks were probably not vapor-tight.

Further details are contained in the emission test report.[14]

4.2.7 Bulk Terminal Test No. 9

Test No. 9 was conducted at a medium size bulk terminal which contains two loading racks. Throughput at the terminal is about 1,440,000 liters (380,000 gallons) of gasoline per day.

Air-vapor mixture is displaced during loading and piped to an REF type control unit. The facility and refrigeration unit were tested on September 20-22, 1976.

In the emission test report, vapor balance and non-vapor balance information was not given on a per-truck basis, but as a percentage of loads which serviced Stage I balanced stations during each test day. Therefore, only runs which indicated either 100 percent (vapor balance) or 0 percent (non-vapor balance) could be used in this analysis. In addition, no previous load designation was given for each tank truck.

Gasoline was assumed to be the previous load based on the following sentence contained in the process description: "Trucks to be loaded carry gasoline vapor-laden air."

Combustible gas detector readings were taken around all vapor return line fittings. The truck/hose connection at the loading rack was found to be leaky and remained so throughout the test period. The top of each truck was also monitored for leaks around the compartment hatches and vapor return piping. A significant amount of leakage was observed in almost all instances. Among the tank truck loadings checked, 10 were determined to be vapor-tight. The corresponding $(V/L)_r$ values were used for calculation of potential emissions.

Further details are contained in the emission test report.[15]

4.2.8 Bulk Terminal Test No. 10

This tank truck gasoline loading terminal contains three bottom-loading racks. Throughput at the terminal is about 830,000 liters (220,000 gallons) per day. Testing was conducted on November 10-12, 1976.

The air-vapor mixture displaced from tank trucks during gasoline loading is routed to a refrigeration type control unit.

Gasoline tank trucks and trailers loading at this terminal serve both non-vapor recovery and vapor recovery equipped service stations. However, only four test runs were attributed to trucks returning from Stage I service stations. Previous load designations were not given on a per-run basis; rather, gasoline was assumed to be the previous load based on the following sentence contained in the process description: "Trucks to be loaded carry a gasoline vapor-air mixture."

Combustible gas detector leakage readings were taken around all vapor return line fittings. The top of each truck was also monitored for leaks around the compartment hatches and vapor return piping. Among the tank truck loadings checked, 16 were determined to be free of leakage. The corresponding $(V/L)_r$ values were used for calculation of potential emissions.

Further details are contained in the emission test report.[16]

4.2.9 Bulk Terminal Test No. 12

Test No. 12 was conducted September 26-28, 1978, at a bulk terminal with a daily average gasoline throughput of 1,500,000 liters (400,000 gallons). Gasoline and distillates are transferred to tank trucks through five loading racks, three of which use bottom loading and dispense gasoline.

Air-vapor mixture is first piped from the loading racks to a liquid knockout tank which removes any liquid gasoline in the line. The mixture passes from the knockout tank directly to a refrigeration type control unit.

Vapor/liquid ratios ranged from .088 m^3/m^3 for a badly sealed truck to 2.00 m^3/m^3 for a truck which produced vapor growth and had fewer vapor leak sources. Tank trucks loaded at the racks were leak-checked using a combustible gas detector. Of those tank trucks tested, 14, 8, and 5 of them were classified as vapor-tight tank trucks on September 26, 27, and 28, respectively.

Gasoline tank trucks and trailers loading at this terminal serve both non-vapor balance and vapor balance equipped service stations.

Further details of this test are contained in the emission test report.[17]

4.2.10 Bulk Terminal Test No. 13

This test was performed at a bulk terminal with an average gasoline throughput of approximately 1,500,000 liters per day (400,000 gallons per day). The terminal contains 14 racks using top splash loading which dispense xylene, fuel oil, and three grades of gasoline. Only the five racks loading gasoline route the displaced vapors to vapor recovery, consisting of a refrigeration control unit. The testing was conducted on October 10-12, 1978.

Top splash loading is the only method of transfer employed at this terminal from storage tank to tank truck. An air balance analysis showed that approximately 48 percent of the displaced air-vapor mixture leaked from the vapor collection system. This severe leakage occurred at several points in the vapor collection system, including the loading arm-truck hatch interface and the relief and check valves. Tank truck leak testing with a combustible gas detector was not practical because of this serious leakage on essentially all trucks. Thus, in order to adjust the data for leakage, the value of $(V/L)_p$ was assumed equal to 1.0 for all runs.

Further details are contained in the emission test report.[18]

4.2.11 Bulk Terminal Test No. 14

Test No. 14 was conducted December 11-12, 1974, at a bulk terminal having an average gasoline throughput of approximately 600,000 liters (160,000 gallons) per day. The terminal has eight loading racks for various fuels, three of which dispense gasoline. Each of the gasoline

loading racks is equipped for bottom loading of premium, regular, and unleaded gasoline. Also, at one of the gasoline racks, two grades of aviation fuel are dispensed, and vapors are vented to the vapor control system.

Vapor hoses at each of the three gasoline bottom-loading racks are routed to a saturator, into a vapor holder, and then to a compression-refrigeration-absorption (CRA) system.

Testing was performed during 39 truck loadings at two loading racks. None of the tankers being loaded at this terminal was making deliveries to a station equipped for vapor balancing during bulk drops.

Combustible gas detector readings were taken around all vapor return line fittings. In some instances, it was felt that a non-zero reading could have been the result of spilled gasoline rather than a leak in the vapor return line. Among the tank truck loadings checked, three were determined to be free of leakage. The corresponding $(V/L)_r$ values were used for calculation of potential emissions.

The only difficulties in testing encountered in the loading of gasoline were vapor leakage and spillage. Vapor losses occurred at almost all hatches and pressure vents at the top of the trucks. Liquid spillage occurred on occasion because of improper seating of the shutoff valve at the liquid connection to the tanker, and also from buckets used to catch a small amount of unleaded gasoline left in the tank truck compartments from the previous load.

Further details are contained in the emission test report.[19]

4.2.12 Bulk Terminal Test No. 16

Test No. 16 was conducted at a terminal containing two loading racks having four bottom-loading dispensing arms each. The gasoline throughput of the terminal is considered confidential by the operator.

Air-vapor mixture displaced from loading tank trucks is directed to a liquid knockout tank, a vapor holding tank, and then to a CRA type control unit. Testing was performed on four days, February 20-21, 1978, and March 8-9, 1978.

No control system upsets or instrument malfunctions were reported during the test. VOC concentrations were measured as volume percent as butane. No measurements of leaks were made with a combustible gas detector, so the value of $(V/L)_p$ is set at 1.0 for the calculations. During the test, tank trucks returned an average of 0.689 cubic meter of air-vapor mixture for each cubic meter of gasoline pumped, indicating that several tank trucks were probably not vapor-tight.

Gasoline tank trucks and trailers loading at this terminal serve both non-vapor balance and vapor balance equipped service stations.

Further details are contained in the emission test report.[20]

4.2.13 Bulk Terminal Test No. 17

This tank truck gasoline loading terminal was tested by EPA on May 2-4, 1978. The terminal has a gasoline throughput of approximately 1,000,000 liters (265,000 gallons) per day.

The total VOC concentration, at both the inlet and outlet of the CRA vapor recovery unit, was continuously monitored and the vapor volumes were determined at these two sampling points. Gasoline and distillates are transferred from storage tanks to tank trucks through four bottom-loading racks.

Test results are based on measurements of tank trucks which were making deliveries to service stations using a vapor balance system, as well as those which serviced non-vapor balance service stations.

Butane served as the basis for all total hydrocarbon measurements. No vapor tightness measurements were performed during this test; therefore, $(V/L)_p$ was assumed to equal 1.0. During the test period, tank trucks returned an average of 0.685 cubic feet of air-vapor mixture per every cubic foot of gasoline pumped, indicating that there was probably some tank truck vapor leakage.

Further details are contained in the emission test report.[21]

4.2.14 Bulk Terminal Test No. 18

Test No. 18 was conducted at a bulk terminal whose daily gasoline throughput averages 1,500,000 liters (400,000 gallons). Gasoline and distillates are dispensed through six loading racks, four of which use bottom loading and dispense gasoline. Testing was performed on August 2-4, 1978. All collected gasoline vapors are controlled by a CRA vapor control unit.

It is estimated that of the total number of gasoline deliveries made each day, only 20 percent had returned from service stations in Stage I areas; the remaining 80 percent made deliveries outside of Stage I areas.

All trucks were tested for vapor tightness with a combustible gas detector, around the hatch covers, relief valves, and vapor line connections on each truck. Five tank trucks were determined to be vapor-tight out of the 59 on which leak measurements were taken. The corresponding $(V/L)_r$ values were used for calculation of potential emissions.

No problems were reported during the testing in regard to the operation of the control unit or test instrumentation. VOC concentrations were measured in volume percent as butane.

Further details are contained in the emission test report.[22]

4.2.15 Bulk Terminal Test No. 19

Test No. 19 was performed at a bulk terminal containing seven loading racks which dispense gasoline and distillates. Three of the racks use bottom loading, and two of these dispense gasoline. The daily gasoline throughput at the terminal is considered confidential by the operator. Testing was performed at the terminal on September 19-21, 1978. The results presented are for only one day of testing, September 21, 1978. Air-vapor leakage at the pressure-vacuum relief valve on one of the unleaded gasoline storage tanks made it necessary to omit the September 19 test data. A disconnected volume meter at the control system exhaust on September 20 invalidated the results from that day. All collected vapors were controlled by a CRA type unit.

Test results are based on measurements of tank trucks in both vapor balance and non-vapor balance service.

There were no significant equipment problems reported during the testing on September 21. Five of the tank trucks were measured to be vapor-tight out of the 19 loadings monitored. The corresponding $(V/L)_r$ values were used for calculation of potential emissions. Total VOC concentrations were measured in volume percent as butane.

Further details are contained in the emission test report.[23]

4.2.16 Bulk Terminal Test No. 20

Test No. 20 was performed at a complex consisting of four bulk terminals whose total average daily throughput of gasoline was

approximately 5.7 million liters (1.5 million gallons). Gasoline is loaded into tank trucks primarily through bottom-loading type dispensers at the four terminals. VOC vapors from all four terminals are routed to a single compression-refrigeration-condensation (CRC) type vapor control unit, whose operation is somewhat similar to that of the CRA unit. Testing was performed on four days, February 1-2, 1978, and March 6-7, 1978.

Gasoline tank trucks and trailers loading at this terminal serve both non-vapor balance and vapor balance equipped service stations. VOC concentrations were measured as volume percent as butane.

No vapor tightness measurements were performed during this test; therefore, $(V/L)_p$ was assumed to equal 1.0. During the test period, tank trucks returned an average of 0.701 cubic meter of air-vapor mixture for each cubic meter of gasoline pumped, indicating that several tank trucks were probably not vapor-tight.

Further details are contained in the emission test report.[24]

4.2.17 Bulk Terminal Test No. 21

Test No. 21 was performed at a bulk terminal containing nine loading racks, five of which dispense gasoline through bottom-loading arms. Daily gasoline throughput at the terminal is considered confidential by the terminal operator. Testing was performed on August 16-18, 1978.

Air-vapor mixture displaced from tank trucks during loading is routed through a saturator, and then to a vapor holder. The vapor holder is followed by a CRC type control unit, which starts automatically when a preset volume level is reached in the vapor holder.

All but one of the test runs were on loading tank trucks delivering to service stations using a vapor balance system.

All trucks were tested for vapor tightness with a combustible gas detector. Three of the tank trucks were found to be vapor-tight out of the 35 loadings tested. The corresponding $(V/L)_r$ values were used for calculation of potential emissions. VOC concentrations were measured as volume percent as butane.

Further details are contained in the emission test report.[25]

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